BIOMASSTRADECENTRE II

WORK PACKAGE 2:

PROMOTION OF NEW INVESTMENTS IN WOOD BIOMASS PRODUCTION

Technical backgrounds for advanced techniques and technologies in biomass production

www.biomasstradecentreII.eu

Authors:

CHAPTER I: Costs of wood biomass production from forests (CRES)
Ioannis Eleftheriadis

CHAPTER II: Wood biomass production in small scale forests (SFI)
Tine Premrl and dr. Nike Krajnc

CHAPTER III: Different aspects of wood biomass production from short rotation plantations (LkStmk)
Loibnegger Thomas and Metschina Christian

CHAPTER IV: Socio-economical aspects of wood biomass production (REGEA)
Velimir Šegon and dr. Julije Domac

CHAPTER V: Environmental aspects of wood biomass production (TUM)
Dr. Johann Kremer

CHAPTER VI: Different aspects of forest residue use, (IrBEA)
Noel Gavigan

CHAPTER VII: Production of wood biomass in case of forest calamites (ICPE)
Dr. Corina Berkesy, Dr. Mihaela Begea, Dr.Laszlo Berkesy

CHAPTER VIII: Wood biomass production in mountain regions (WVB-Stmk GmbH)
Bernd Poinsitt

CHAPTER IX: Wood biomass production in large scale forests (TUM)
Dr. Johann Kremer

CHAPTER X: Different aspects of wood biomass production from non-forest land (AVEBIOM, AIEL)
Massimo Negrin, Valter Francescato, Pablo Rodero, Juan Jesús Ramos

CHAPTER XI: Drying of wood – forest chips (CTFC)
Mireia Codina and Ignacio López

Editor: Bernd Poinsitt

Supported by: Intelligent Energy – Europe (IEE)

In the frame of: BiomassTradeCentreII project (Grant agreement no. *IEE/10/115/SI2.591387)*

January 2012
Published on: http://www.biomasstradecentre2.eu

ID_3360934

INTRODUCTION

At the beginning of the project Biomasstradecentre II, partners prepared a list of relevant topics on advanced techniques and technologies in biomass production. This document delineates technical backgrounds for advanced techniques and technologies in biomass production and gives an overview of the latest research and development achievements in this field. The gathered material will be used as background material for the preparation of workshops and trainings.

This document was prepared by partners from different participating countries and represents the collection of available information's about wood biomass production chains. Different sources used in preparation of this document are listed at the end of each chapter.

This limited collection of existing knowledge in the field of wood biomass resources and technologies can be used by farmers and forest owners, forest entrepreneurs and companies, members of machinery rings, experts working in this field or by others interested in wood biomass.

Dr. Nike Krajnc
Project coordinator

TABLE OF CONTENT

List of figures

List of tables

I. COSTS OF WOOD BIOMASS PRODUCTION FROM FORESTS

Prepared by: Ioannis Eleftheriadis (CRES)

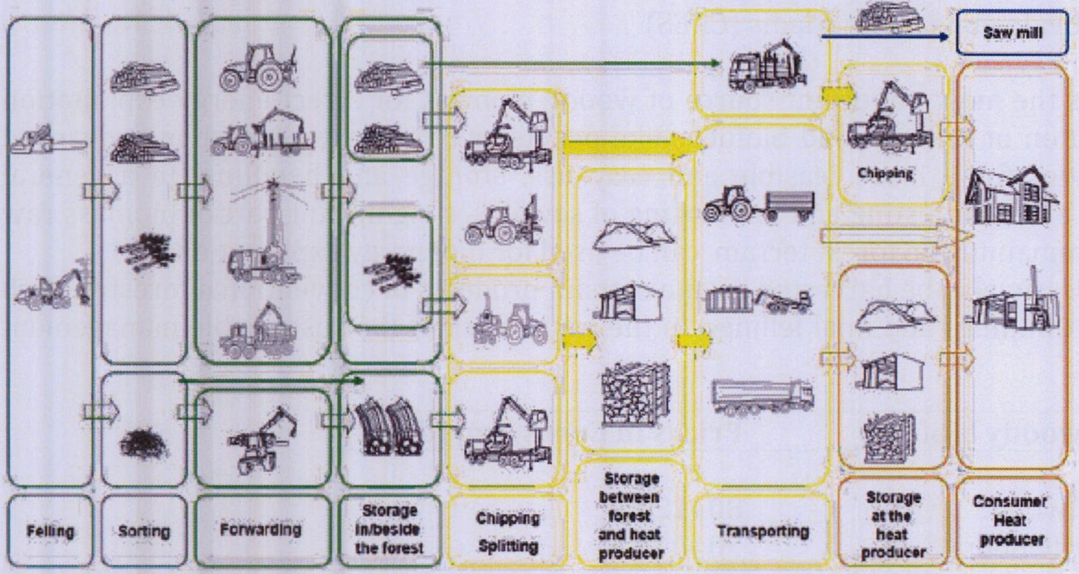
Forestry is the most important source of woody biomass for direct energy exploitation or production of refined solid biofuels, like pellets or other materials, giving advanced opportunities for a more feasible and easy use, storage and handling. In a general approach, after harvesting and forwarding of sawlogs, a significant part of biomass raw material, remaining on forest terrain, can be used for bioenergy exploitation.
Wood fuels can also be harvested as one of main products of conventional forestry, such as annual thinnings and final fellings, in the framework of the sustainable management of forests.

Types of woody biofuels	Prices in Euros/ton (dry)
Fire logs:	
Softwood:	80 -120 +
Hardwood:	70 -150 +
Forest residues - wet, chipped:	60 -80
Industrial residues:	
chips:	70 -90
sawdust:	50 -70
others:	40 -60
Recycled wood:	50 -70 (less if contaminated)
Pellets:	160 -220
Oil equivalent:	230 -250

TABLE 1: WOODY BIOFUELS PRICES IN GERMANY, 2006

The production cost of forest biomass for bioenergy exploitation is an important factor affecting the retail prices of all woody biofuels, the competition with fossil fuels and woody by-products, as well as, the penetration of forest biomass in the energy balance. Due to different forest conditions (e.g. exploitation system, forest terrain, roads' network) the exploitation schemes of woody biomass from forests must be assessed separately (case by case). Table 1 presents an example of the range of prices for woody biofuels.

Woody biofuels' prices are generally competitive to prices of fossil fuels. Forest woody biomass is an environmentally friendly resource for bioenergy exploitation but competes with other use for wood products. This competition could increase the price of all wood products in the market, including solid biofuels.



Source: AFO project (http://www.afo.eu.com)

FIGURE 1: WOOD FUEL SUPPLY CHAINS FOR BIOENERGY EXPLOITATION

In the forest practice, many harvesting systems have been developed for the exploitation forest biomass. Figure 1 presents different wood supply chains for bioenergy production. The harvesting cost of forest biomass in these systems varies, due to different working methods and different machinery have been used. Wood chips and firewood are the main products of forest biomass exploitation schemes that are used for bioenergy production. Firewood is produced from stemwood during the harvesting process. Cross-cutting and splitting of stemwood is necessary for the handling of this type of biofuel. Wood chips are derived by the further process (chipping) of different fractions of forest biomass.

Generally, the estimation of the annual harvesting cost of forest biomass is based on the following equation:

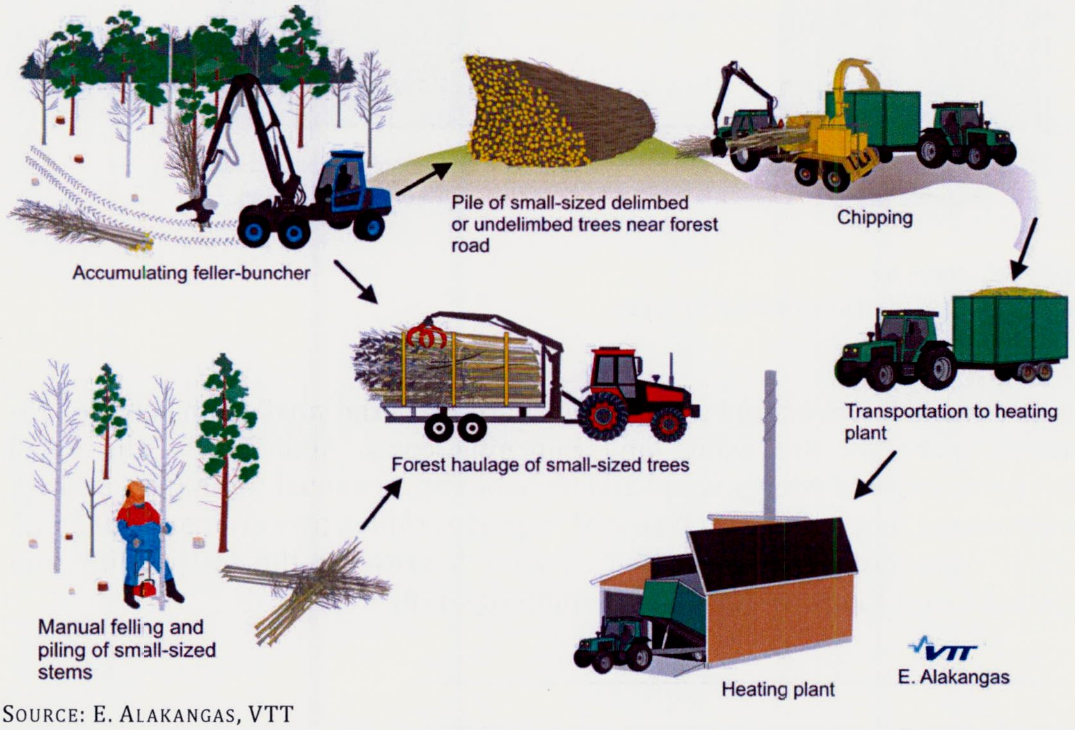
$$HC = \left[\left(\frac{I - SV}{SL} + \frac{I}{2} * \frac{AR}{100} + ME + LC + FC\right) * \frac{1}{WH} * \frac{100}{EM}\right] * \frac{1}{P} \qquad [3]$$

Where:

HC = harvesting cost, in €/m^3
I = investment, in €
SV = scrap value, in €
SL = service life of machinery, in years
AR = rate, in %
ME = expences for maintenance and repairs, in €/year
LC = labour cost, in €/year
FC = fuels cost, in €/year
WH = annual working hours
EM = annual use efficiency of machinery, in %
P = productivity, in m^3/hour

A. Wood chips production

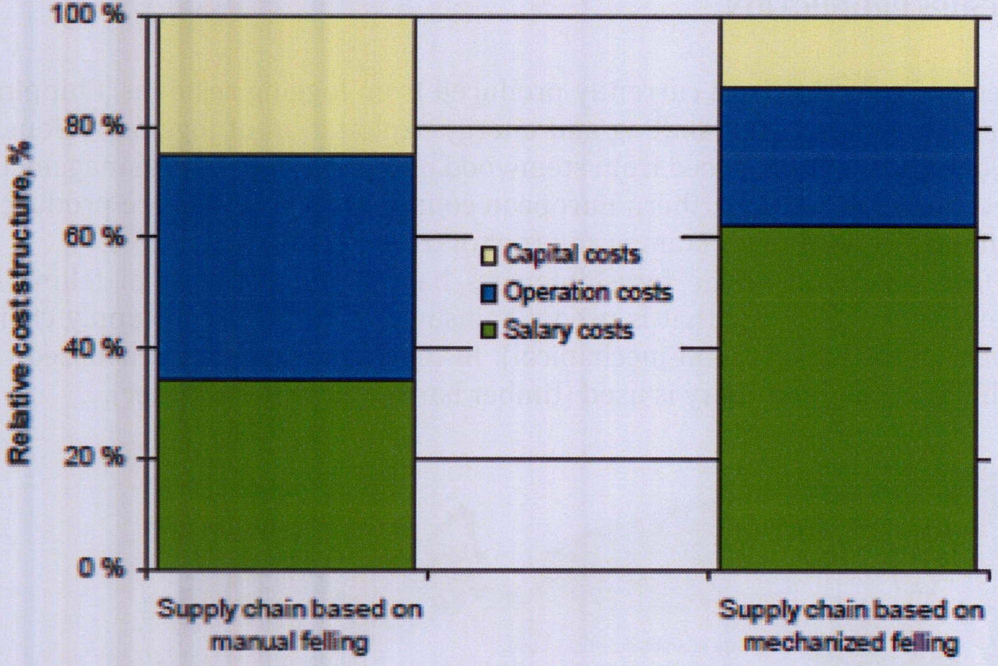
Large quantities of forest chips are currently produced from logging residues. Chipping is a recomended process for the handling and energy exploitation of logging residues. Additionally, wood chips are produced from stemwood of when whole-tree management is used as harvesting system. In Northern European countries, wood chips are produced from the exploitation of wood from stamps and root of trees in the forests.
Felling is the first operation of the forest biomass harvesting. The cost of felling is affected by the type of machinery that is used. Chainsaws are used in the supply chain that is based on manual felling (semi-mechanical). In the supply chain that is based on mechanized felling special machinery is used (timber harvester, feller buncher).



Source: E. Alakangas, VTT

Figure 2: Wood chips supply chain for heat production (manual and mechanical felling)

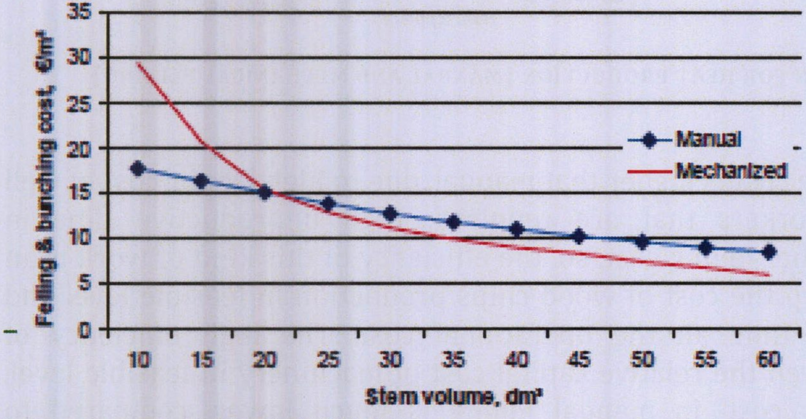
The mechanical felling relative cost is higher that manual, due to high labour cost of well experitised and trainned workers that are required. High unproductive time in mechanical felling creates higher felling cost, so, the efficiency of this kind of work is an important factor that will keep the cost of wood chips production in feasible level and will reduce the operational time an the operational cost. The high efficiency of mechanical operations will keep the relative capital cost of machinery in feasible level, as well. The relative labour cost, in manual felling is much lower, compared to mechanical, but, requires more working time which increases the operational costs (Figure 3)



SOURCE: LAITILA, 2005, METLA [10]

FIGURE 3: TYPICAL COST STRUCTURE OF FOREST CHIPS

The logging cost of small size energy wood is high because of the small stem volume (15-45 dm^3) which increases the felling and bunching costs. Additionally, the small accumulation per hectare of energy wood and its handling, in annual thinnings, has high cost. It was estimated that organization cost of logging residues procurement is 0,7 -1,3 €/$m^3$and small trees procurement 2 €/m^3. Figure 4 presents the total felling and bunching costs of forest biomass from annual thinnings. [10]

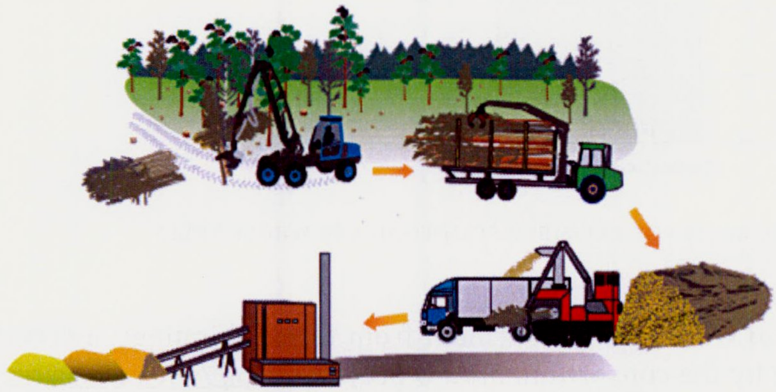


SOURCE: LAITILA, 2005, METLA [10]

FIGURE 4: FELLING BUNCHING COSTS OF LOGGING RESIDUES FROM ANNUAL THINNINGS

1. *Wood chips production from stemwood*

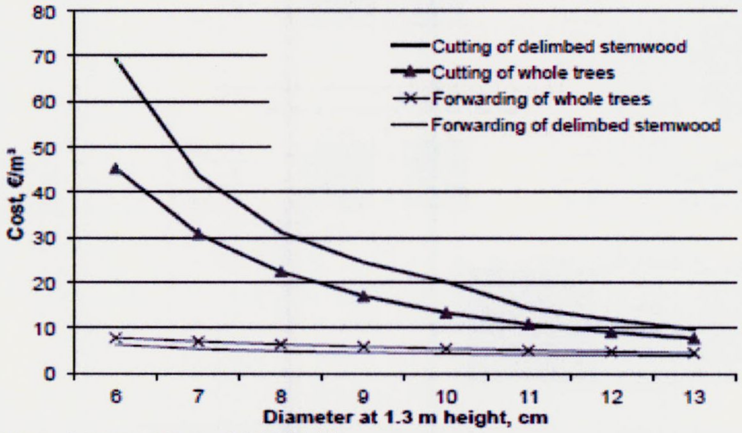
Thinning of forests trees is an important process of forest management. Small diameter trees that are harvested is an significant source of woody biomass that is mainly used for bioenergy production. Chipping of this raw material is necessary for the efficient use as biofuel and the production of energy in units using wood chips as fuel. In this process the cost of logging is the most important due to the method that will be used. It was previously mentined that the efficiency of mechanical operations affects the total cost of wood chips and will keep the price of wood chips in feasible level. After the felling of trees, delimbing of stemwood might be decided due to sulvicultural and management issues. Forwarding of delimbed stemwood or whole trees is required for the moving of biomass from the forest terrain to the forest road for further process. After chipping, wood chips are transpoted to final use with trucks or trailers (Figure 5).



Source: E. Alakangas, VTT

Figure 5: Forest biomass exploitation scheme based on the whole tree management, with chipping at the forest roadside and transport with trucks

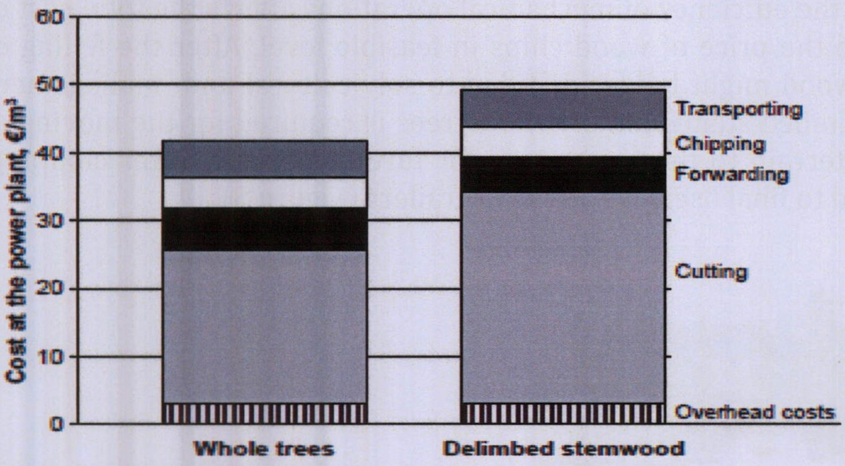
The production cost of wood chips from delimbed stemwood is higher (~50€/m^3) than the case where whole tree management is used as exploitation system. (Figure 7, [11])



Source: Lait la et al., 2010 [11]

Figure 6: Logging and forwarding costs for delimbed stemwood and whole trees

The use of delimbing process is another important factor that affects the production cost of weood chips. The delimbing of stemwood significantly increases the cost of wood chips and desreases the cost of forwarding but this decrease is very little. As a general approach, delimbing increases the cost of wood chips. The effect of delimbing in the production cost of wood chips is decreased when the DBH of harvested trees is increased. (Figure 6, [11])



SOURCE: LAITILA ET AL., 2010 [11]

FIGURE 7: LOGGING AND FORWARDING COSTS FOR DELIMBED STEMWOOD AND WHOLE TREES

In ordet to estimate the cost of wood cips procurment from forest thinnings, a specific tool (Figure 8) was developed by the consortium of AFO project (http://www.afo.eu.com), that is available as a web application in the project's web-site (http://www.afo.eu.com/calculators/ENG/calc1/).

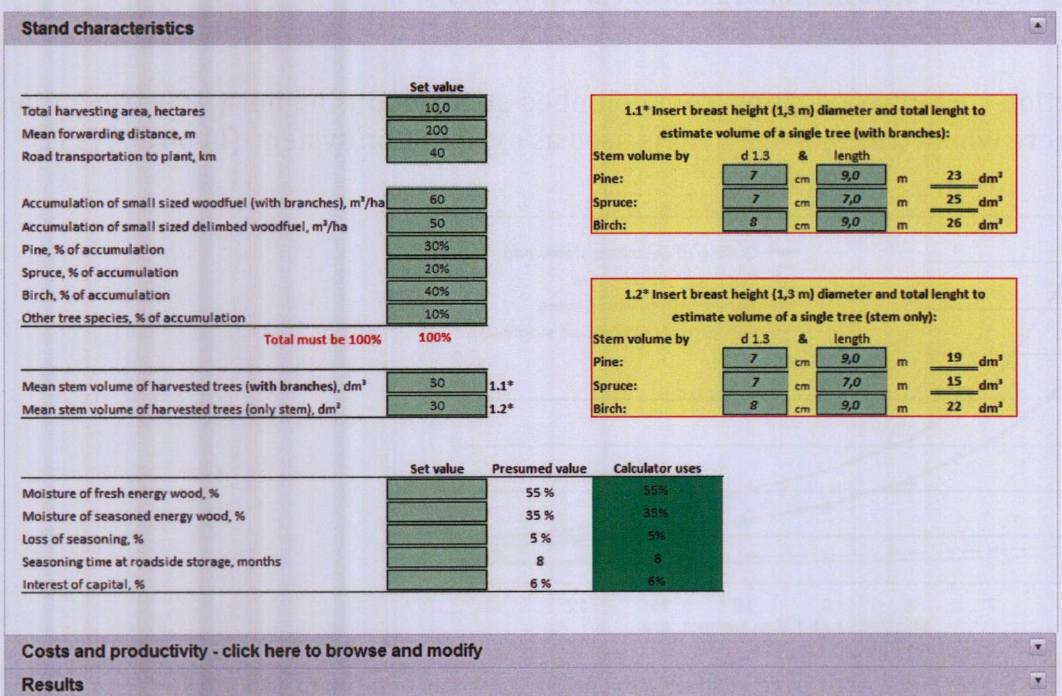


FIGURE 8: COST CALCULATOR FOR WOOD CHIP PROCUREMENT FROM THINNINGS

In this forest biomass supply chain, the forwarding productivity is much higher after mechanized felling compared to manual felling. That creates a cost difference between to methods which was estimated at about 3 €/m^3 of forwarded material (7,5€/m^3 for the manual method and 4,4 €/m^3 for the mechanized method). Delimbing of trees after felling increases the efficiency of forwarding, in about10 -20 % compared to whole trees management, due to the higher bulk density and load volume. The load volume of whole tree was determined at 4 –7 m^3, instead of delimbed trees which was determined at 8-10 m^3. [10]

2. *WOOD CHIPS PRODUCTION FROM LOGGING RESIDUES*

Logging residues is currently the main resource for forest chips production in Europe. For the harvesting and use of logging residues two basic supply chains have been developed:

1. Logging residues – Forest site chipping - Transport with trucks in separate containers

    a. terrain chipping method
    b. chipping at roadside method

2. Logging residues - Forwarding to forest roads - Transportation with trucks - Chipping at the end use site

    a. bundling method
    b. loose residues method

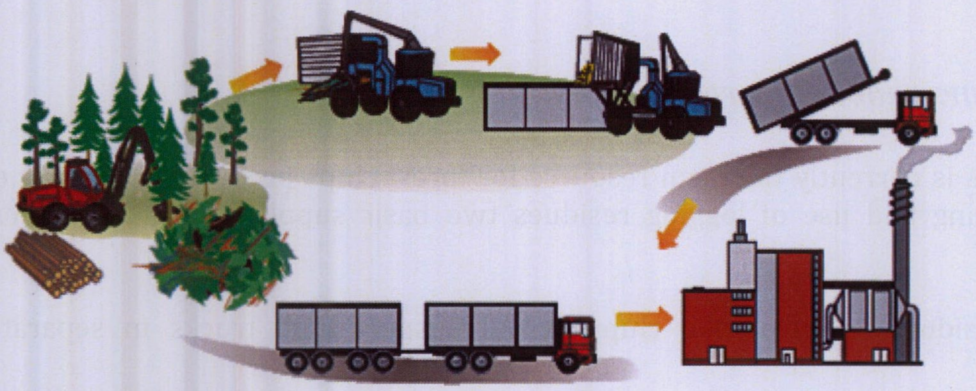
In forest practice there is no scheme, for the harvesting and supply of forest chips, which could be implemented in any exploitation system. Several factors are taken into account in order to determine which forest chip supply scheme will be used. Some of these factors are listed below [9]:

- The harvesting conditions
- The roadside landing capacities
- The transportation distances
- The operating volumes and storage capacities
- The availability of machinery
- The type of forest chips
- The total costs of supply systems

a) Logging residues – Forest site chipping - Transport with trucks

The first logging residues supply chain is based on the chipping of raw material on the forest terrain and the transportation of chipped material with trucks to the final users. Logging residues are accumulated in the felling area and are chipped with high efficiency mobile chippers. In this supply chain forwarding of residues to the forest road, before chipping, might be included due the biomass exploitation system and the different arrangement of harvesting operations (Figure 9).

In the forest residues exploitation scheme that is based on road side chipping the chipping and transportation processes are dependent on each other. The operating time for chipping or transportation might be wasted by unproductive time (waiting). The low degree of capacity utilization of machinery creates high chipping costs. This harvesting system based on roadside chipping is suitable for small and medium scale applications. [10]



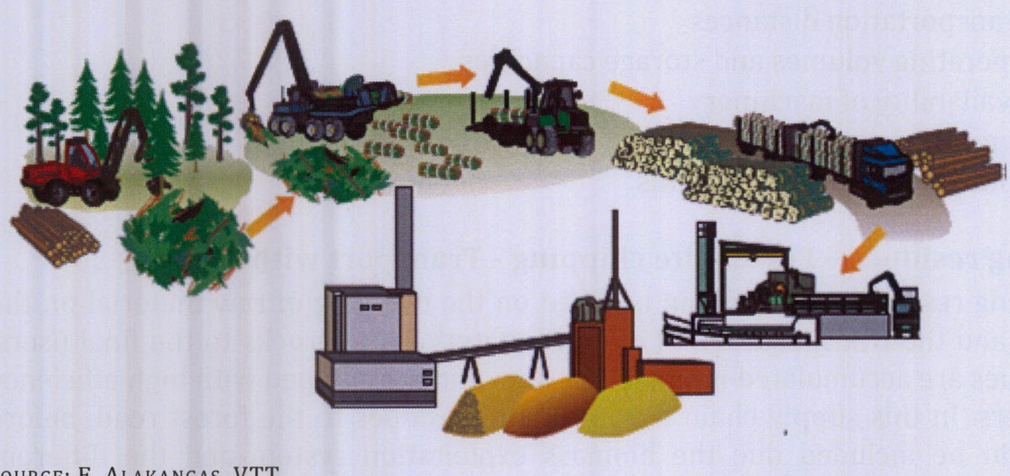
Source: E. Alakangas, VTT

Figure 9: Forest biomass exploitation scheme based on logging residues handling, off road chipping and transportation with trucks in separate containers

Generally, the biomass production and supply chain, which is based on forest site chipping, is more efficient in smal or medium scale forest exploitation systems.

b) Logging residues - Transportation with trucks – Chipping at the end use site

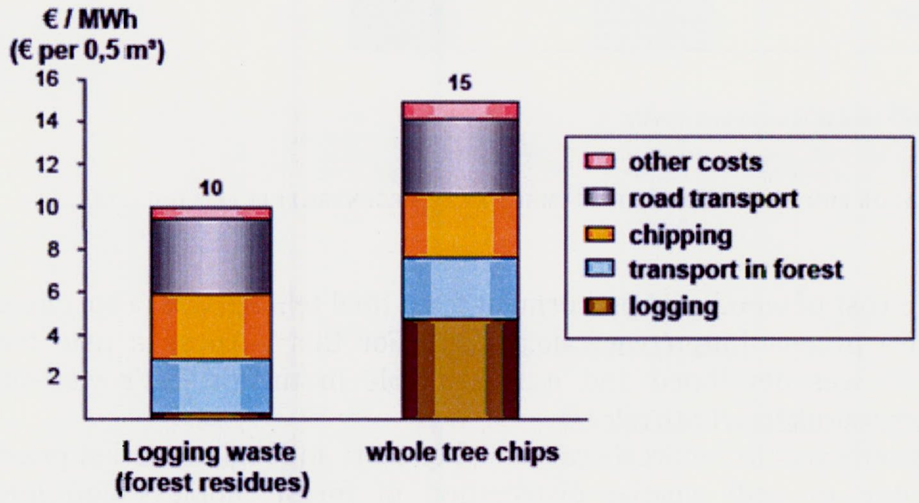
Alternatively, first logging residues after felling, delimbing accumulation on site are bundled using special machinery (bundling machines). After this process bundles are forwarding to the forest roadsides for transportation to the final users, where they will be chipped (Figure 10). The low bulk density of the unprocessed material is a disadvantage of the end-use facilities chipping system. Bundling and delimbing of small trees improves the bulk density and reduce costs.



Source: E. Alakangas, VTT

FIGURE 10: FOREST BIOMASS EXPLOITATION SCHEME BASED ON LOGGING RESIDUES HANDLING, BUNDLING AT LOGGING SITE, FORWARDING TO FOREST ROADS, TRANSPORTATION WITH TRUCKS AND CHIPPING AT THE PLANT

The end use facility chipping scheme is suitable only for large plants since the investment cost is high. Bundling is an extra cost in the process of logging residues exploitation but, improves the efficiency of transportation (high bulk density). The bundling cost, for spruce logging residues, was estimated at 3,5 €/bundle that is equivalent to 6,4 €/m^3, based on productivity of bundling machine that was determined at 20 -25 bundles per operating hour. An advantage of this scheme low chipping costs, when it is done at the power plant or large scale procurement methods are implemented. [10]
The forwarding cost of bundles from logging residues was estimated at 3 €/m^3 which is the 50% of the forwarding cost of loose logging residues, which was estimated at 6 €/m^3. The main reason for that is the load capacity of forwarders which was ranged from 6 to 12 m^3 (10-20 bundles) instead of 4 –7 m^{3}for loose logging residues. [10]
Generally, the harvesting of logging residues is used only in the method of clear fellings and it is less efficient in the method of annual thinnings due to higher costs that caused by the movement of machinery used in forests during thinning operations. Whole tree management is more feasible in annual thinnings.



SOURCE: VTT
FIGURE 11: PRODUCTION COST OF WOOD CHIPS FROM LOGGING RESIDUES AND WHOLE TREE MANAGEMENT.

The production cost of wood chips from logging residues, compared to the production from whole tree management, is significantly higher (Figure 11). The cost of forest chips from logging residues was estimated by VTT at 10€/MWh instead, of chips from whole trees that its cost was estimated at 15€/MWh [5].
The chipping at the end user facilities makes chipping and transportation-delivery operations independent of each other. The high degree of capacity utilization of these facilities creates low chipping costs. [10]
It is obvious from Figure 11, that the high logging cost increases the total cost of forest chips production in the framework of biomass harvesting that is based on the whole tree management.

In large scale forest exploitation systems, the high efficiency harvesting operations and the development of biomass supply chains, based on chipping at the location of the final user, operations, support the production of low cost forest biomass. [10]

Stand characteristics

Accumulation of industrial roundwood, m^3

Pine sawlog, m^3	45
Spruce sawlog, m^3	39
Broadleaf sawlog, m^3	37
Pine pulpwood, m^3	40
Spruce pulpwood, m^3	40
Broadleaf pulpwood, m^3	65
Industrial roundwood in total, m^3	266

Felling area, ha	1,0
Mean forwarding distance, m	150
Road transporting distance to heat/power plant, km	60

	Insert value	Presumed value	Model uses
Moisture of logging residue %, green residue		55 %	55%
Recovery %, green residue		70 %	70%
Moisture of logging residue %, dried at roadside storage		45 %	45%
Loss of drying %, dried at roadside storage		10 %	10%
Moisture of logging residue %, dried on stand before forwarding		40 %	40%
Loss of drying %, dried on stand before forwarding		20 %	20%
Mean distance between skidding trails on the felling area, m		15	15
Storage time in roadside storage, months		4	4
Interest of capital, %		6 %	6%

Costs and productivity - click here to browse and modify

Results

FIGURE 12: COST CALCULATOR FOR WOOD CHIP PROCUREMENT FROM REGENERATION FELLING SITES.

The estimation of the cost of wood cips procurment from final fellings was, also, one of the objectives of AFO project (http://www.afo.eu.com). For this purpose a new tool (Figure 12, Figure 8) was developed and it is available in the project's web-site (http://www.afo.eu.com/calculators/ENG/calc2/)

High woody biomass removals from forests cause higher costs and higher market prices for solid biofuels, due to wide spatial distribution of forest biomass and long transportation distances that are required for the supply of forest chips from logging residues and stumps (Figure 14, [13]). Thus, the scale of forest operations has significant impact on the production cost of woody biomass for energy purposes. [10]

The chipping cost in Finland was estimated at 5,3 € per $m^3$of the produced material, for the roadside chipping and at 1,8 € per m^3 , when chipping takes places at the location of the final use (bioenergy plant). [10]

Table 2 presents an estimation of biomass production cost for different forest management systems and different exploitation systems where other type of machinery had been used.

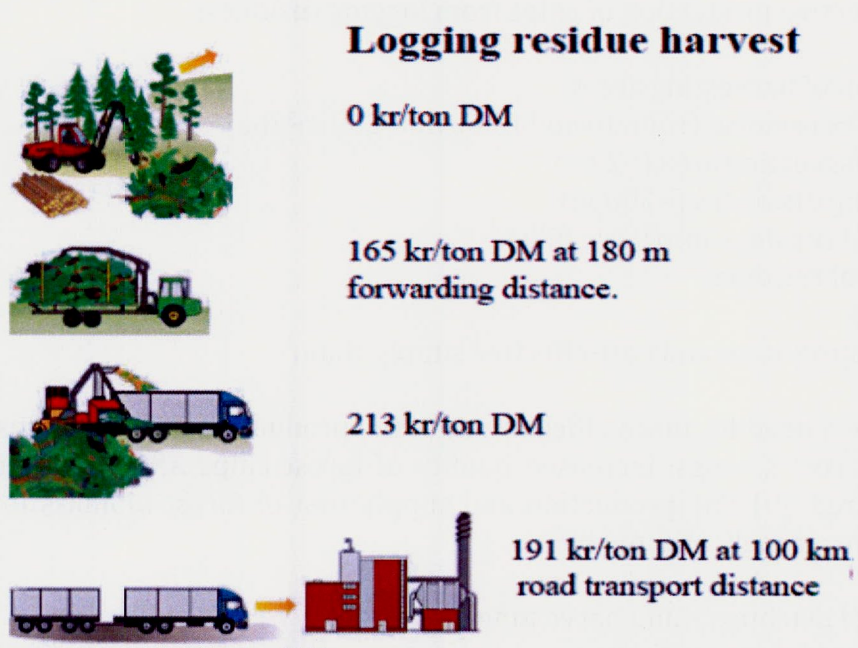
Reference	Communition Device	Type[a]	Description of Forest Residues	Productivity[b]	Cost (PMH) (US$ 2002)
Bolding 2002	Bandit 1850 Whole Tree Chipper	M	Limbs and tops from merchantable pine and hardwood thinning; and non-merchantable trees 0.5 – 4.0 inches DBH.	20.24 gt[c]/pmh (11.54 bdt[d]/pmh)	$1.73/gt ($3.04/bdt[c])
Asikainen and Pulkkinen, 1998	Evolution 910R Drum Chipper	M	Logging residues from spruce-dominated final fellings in Finland	11.5 10^3 kg/pmh (dry mass)	$11.38/ bdt[d,e]
	MOHA Chipper Truck	S		4.7 10^3 kg/pmh (dry mass)	$17.83/ bdt[d,e]
	Morbark 1200 Tub Grinder	M		9.0-10.5 10^3 kg/pmh (dry mass)	$11.29/ bdt[d,e]
Hartsough et al., 1994	Morbark 60/36 Drum Chipper	M	Logging residues, piled tops and larger limbs, trees <10-inches dbh	NA	$5.46-10.68/bdt[d]

[a] M = Mobile, not self-propelled; S = Self-propelled
[b] PMH = Productive machine hour; SMH = Scheduled machine hour
[c] gt = green tons
[d] bdt = bone dry ton
[e] conversions made by author for FIM (1998) to USD(2002); SMH to PMH; and 10*3 kg to tons (US-short).

Source: Mitchell, Dana L. 2005. Assessment of Current Technologies for Communition of Forest Residues

TABLE 2: BIOMASS PRODUCTION COSTS FOR DIFFERENT MANAGEMENT ACTIVITIES AND EXPLOITATION SCHEMES

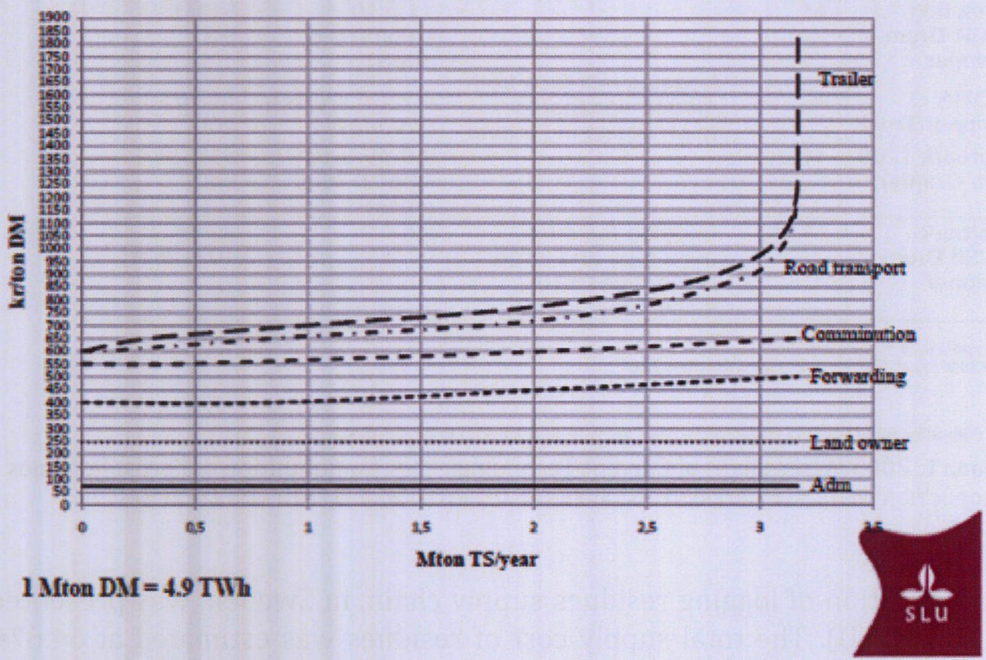
A study for cost estimation of logging residues supply chain, in Sweden, was presented by Magnus Matisons (SLU). The total supply cost of residues was estimated at 64.67€ per dry ton of produced material delivered at the gate of the final user, in a transportation distance of 100km. (Figure 13).



SOURCE: MAGNUS MATISONS, SLU

FIGURE 13: COSTS DISTRIBUTION OF WOOD CHIPS PRODUCTION CHAIN FROM LOGGING RESIDUES

Figure 14 also presents the distubution of biomass supply costs in the previous study. Today, a GIS-based analysis and a cost analysis could give us the ability for lower cost biomass production, better management of forest biomass production and handling and development of more efficient supply chains. [10]



SOURCE: MAGNUS MATISONS, SLU

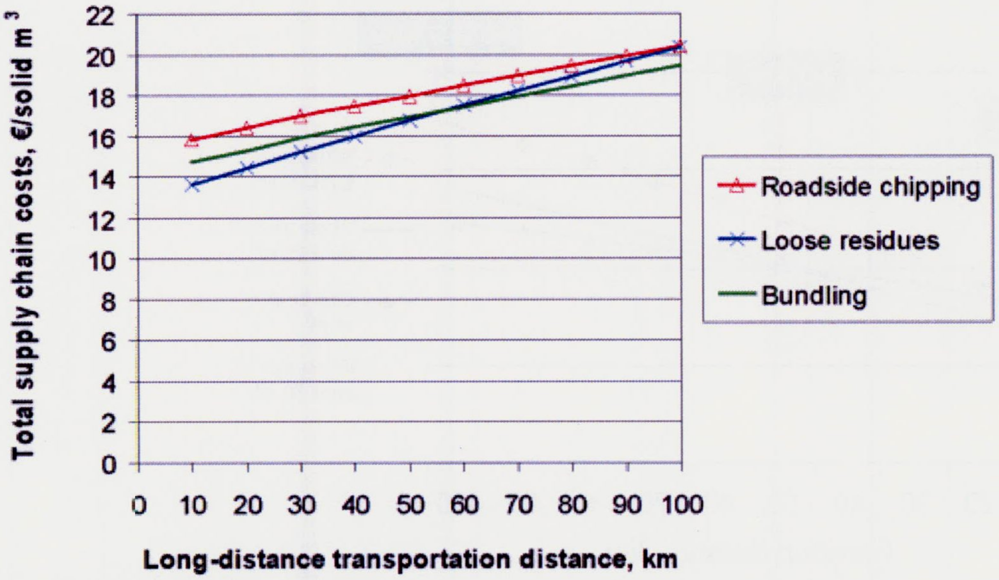
FIGURE 14: COSTS OF WOOD CHIPS PRODUCTION CHAIN FROM LOGGING RESIDUES

Prerequisites for cost-effective production of chips from logging residues:

1. Careful selection of harvesting areas
2. Efficient residues removal (roundwood removal >200 m^3/ha)
3. Large enough harvesting area (>2 ha)
4. Short forwarding distances (<300 m)
5. Accumulation of residues into large piles
6. Natural drying of residues
7. Efficient storage
8. Applying the appropriate and cost-effective supply chain

In the future there will be a need for more efficient use of the production of forest chips. In order to archive that cost savings, increased quality of forest chips and increased production will be required. [9] The production and supply cost of forest biomass for bioenergy exploitation are strongly affected by:

1. The efficiency of machinery and harvesting operations
2. The availability of forest production
3. The forwarding, transportaion distances and load volume
4. The biomass supply chain (Figure 15)



Source: Kärhä & Vartiamäki, 2006

FIGURE 15: TOTAL COSTS FOR DIFFERENT FOREST BIOMASS SUPPLY CHAINS FOR LOMG TRANSPORTATION DISTANCES

The load volume for material transportation is another factor affecting the transportation cost of forest biomass, in combination with transportation distance and the type of transporated material. Different bulk density of chipped and unchipped logging residues has significant effect on the supply cost of biomass in different distances. In a general approach, the cost of unchipped material is lower in distances up to 50 km. The supply of forest chips is more feasible for transportation in distances more that 50 km (Figure 16). [10]

For the estimation of forest biomass production costs two methods can be used. The marginal cost method and the full cost method. In the first method logging operations costs in conventional forestry are not counted but only additional costs after logging are used within that estimation. That means that the logging residues, accumulated on forest site has no cost. In the full cost method all cost included in the biomass and wood products production chains are allocated to all phases of these chains. The implementation of these to methods will create a gap between estimations. [6], [13]

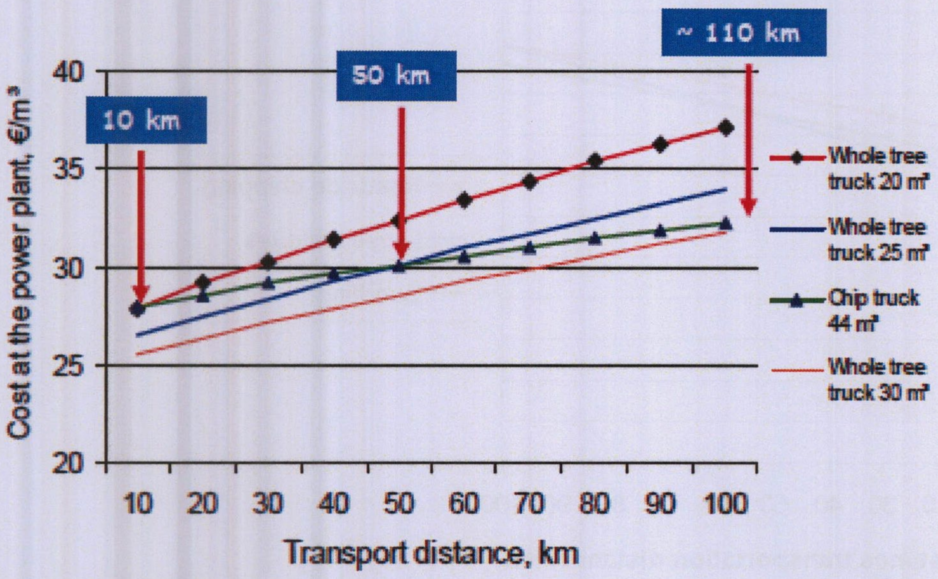


FIGURE 16: SUPPLY COST AS A FUNCTION OF TRANSPORT OF DISTANCE AND LOAD VOLUME

The expected increased demand for forest biomass for energy production, in the future, will require longer transportation distances, pressure on supply costs, better management of supply chains and costs reduction and quality management for forest chips. [9]

The comparison of two forest harvesting methods, producing of the same type of biomass in different costs, is based on the estimation of critical production quantity:

$$CPQ = \frac{FC_2 - *FC_1}{VC_1 - VC_2} \quad [3]$$

Where:

CPQ = critical production quantity, in m³/year

FC_1 = fixed costs of first method, in €/year

FC_2 = fixed costs of second method, in €/year

VC_1 = variable costs of first method, in €/ m³

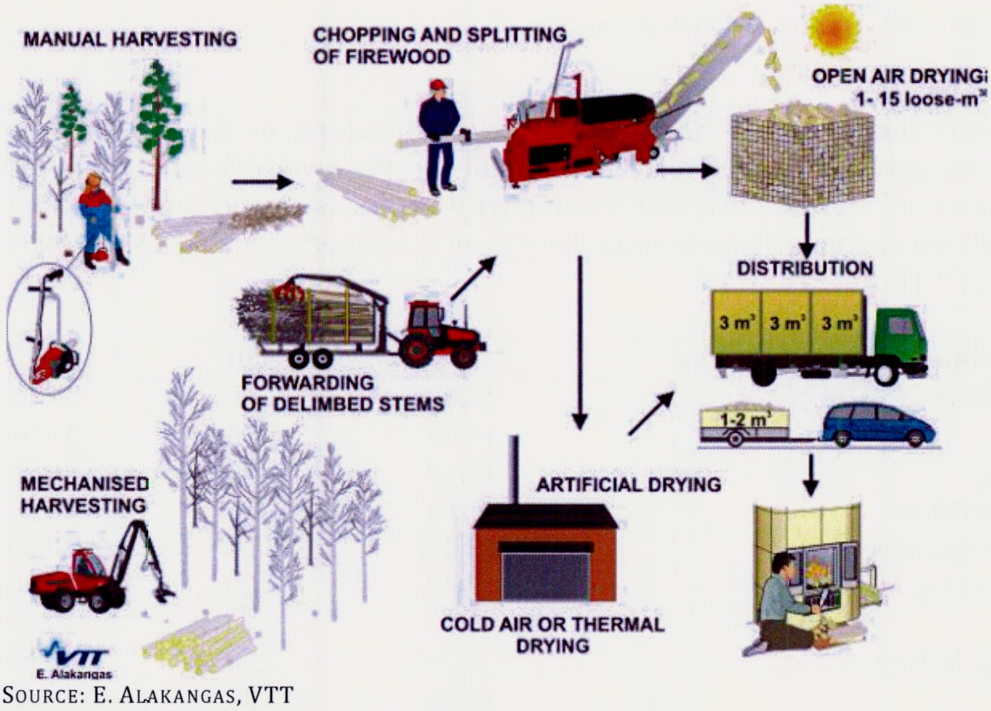
VC_2 = variable costs of second method, in €/ m³

The critical production quantity indicates the point where the increment production quantities convert the lower costs method to higher costs method and vice-versa.

B. FIREWOOD PRODUCTION

Firewood in the most common type of solid biofuels that is used for residential heating. So, the production of firewood in low cost will create a biofuels competitive in the wood fuels market. The establisment of a production and delivery chain is devided in the follwing phases (Figure 17):

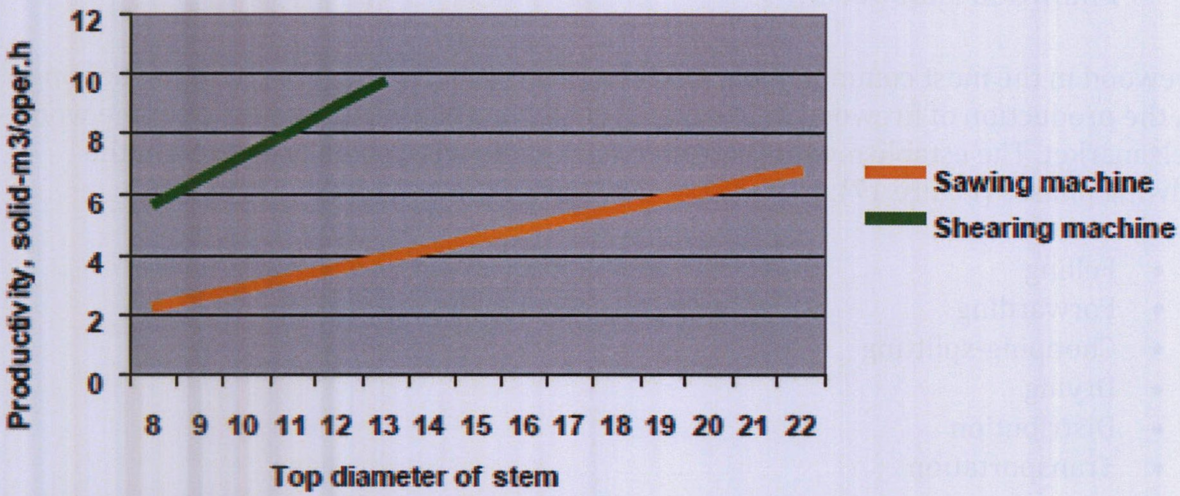
- Felling
- Forwarding
- Chopping-splitting
- Drying
- Distribution
- Transportation



SOURCE: E. ALAKANGAS, VTT

FIGURE 17: FIREWOOD SUPPLY CHAIN FOR HEAT PRODUCTION

Felling cost is almost the same for both manual and mechnized harvesting. Harvesting of stemwood in annual thinnings creates condition for increased cost of further operations due to more working time that in necessary for handling of raw material and moving of machinery within the trees of the forest and the wide spatial distribution of unprocessed biomass.



SOURCE: JYRKI RAITILA, VTT

FIGURE 18: PRODUCTIVITY OF SPLITTING FIREWOOD PROCESS

Delimbing of stems increases the harvesting cost but handling of delimbed stems reduces the bulk density is accomulated material and creates favorable conditions for low cost fowarding of stems. Cost and productivity of cross-cutting and splitting operations are related to stems diameter and the type of machinery which is used in this process. (Table 3, [19])

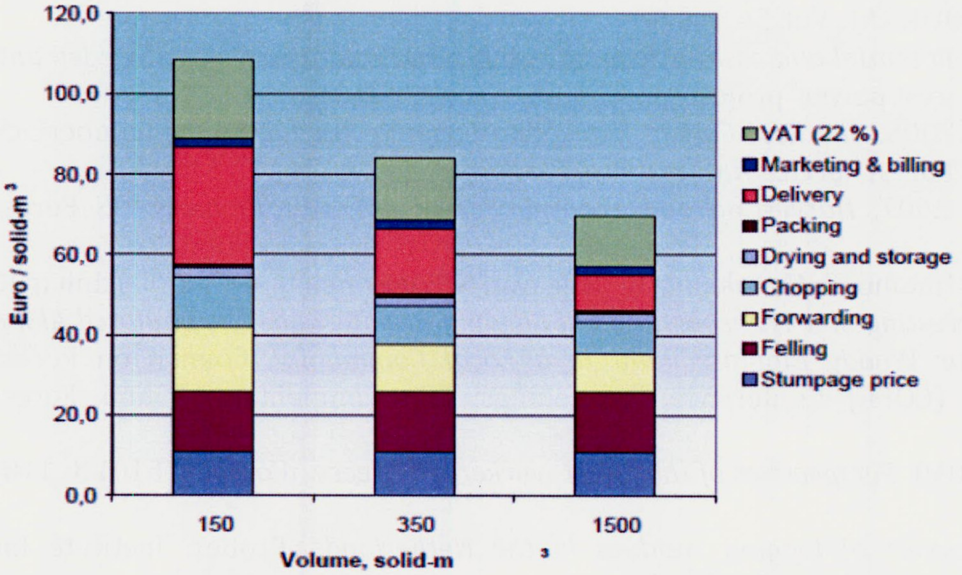
Production volume per year, solid m³	**150**	**350**	**1500**
Stumpage price	11,00	11,00	11,00
Felling	15,00	15,00	15,00
Forwarding	16,10	11,70	9,20
Harvesting, €/solid-m³	**42,10**	**37,70**	**35,20**
Chopping & splitting	12,20	9,60	8,00
Drying & storing	2,20	2,20	2,20
Packing	0,70	0,70	0,70
Marketing & billing	2,20	2,20	2,20
Delivery	29,30	16,30	8,90
Production and delivery, €/solid-m³	**46,60**	**31,00**	**22,00**
Total, €/solid-m³ (without VAT)	**88,80**	**68,70**	**57,20**

TABLE 3: FIREWOOD PRODUCTION COST IN FINLAND, IN €/SOLID M³ (JYRKI RAITILA, VTT, 2008)

Open air drying has higher cost efficiency compared to artficial drying (oven drying). Oven drying is high recomanded when air drying is not feasible or strict technical specifications are required by the market.

Table 3 and Figure 19 present a distribution of harvesting production and delivery costs for specific harvested quantities in Finland. The estimated cost for forwarding, splitting-cross-cutting and delivery are strongly affected by the harvested and handled quantities of raw material.

It is clear that the harvested quantities have significant effect on the production and delivery costs of splitted, dried and packed firewood. Especially, the delivery cost of firewood will be reduced, in a very low level, when produced and handle quantities will be significantly increased, due to more efficient used of machinery. [19]



SOURCE: JYRKI RAITILA, VTT

FIGURE 19: PRODUCTION COST OF FIREWOOD SUPPLY CHAIN FOR HEAT PRODUCTION

C. REFERENCES

[1] D. Abbas, 2007, *Harvesting forest biomass for energy in Minnesota: an assessment of guidelines, costs and logistics*, University of Minnesota

[2] D. Current and D. Abbas, 2006, *Economics of Biomass Harvest*, Woody Biomass Harvesting Workshop and Equipment Demonstration

[3] P. Efthimiou, 2011, *Harvesting of Forest Products*, Aristotle University of Thessaloniki (in Greek)

[4] M. Eker. 2011, *Assessment of procurement systems for unutilized logging residues for Brutian pine forest of Turkey*, African Journal of Biotechnology Vol. 10(13)

[5] A. Frühwald, 2007, *Technologies and Economics of Energy Generation from Logging Residues and Wood Processing Waste*, International Conference on Wood-Based Bioenergy, Hannover

[6] J. Gan; C. Mayfield, 2007. *The Economics of Forest Biomass Production and Use*, Forest Bioenergy (www.forestbioenergy.net)

[7] M. Kallio, A. Leinonen, 2005, *Production technology of forest chips in Finland*, BIO-SOUTH project, EIE/04/255/S07.38609

[8] K. Kärhä, 2006. *Whole-tree harvesting in young stands in Finland.* – Forestry Studies, Metsanduslikud Uurimused 45, 118–134

[9] K. Kärhä, T. Fredriksson, 2008, *Towards More Cost-Effective Production of Logging Residue Chips from Final Cuttings*, IEA Bioenergy International Workshop "Woodfuel Supply Chain –Sharing Experience", Warwick, England

[10] J. Laitila, 2005, *Cost structure of supply chains in Finland*, Northern Wood Heat Symposium, Joensuu, Finland

[11] J. Laitila, J. Heikkilä, P. Anttila, 2010. *Harvesting alternatives, accumulation and procurement cost of small-diameter thinning wood for fuel in Central Finland*, Silva Fennica 44(3): 465–480.

[12] D. Loeffler, D. Calltin, R. Silverstein, 2006, *Estimating volumes and costs of forest biomass in Western Montana using forest inventory and geospatial data*, FOREST PRODUCTS JOURNAL, Vol. 56, No. 6
[13] M. Matisons, *Potential and cost for logging residue and stump harvest in Sweden and BA region*, 'Forest power' project
[14] D. Peterson, 2005, *The Real Cost of Extracting Logging Residue Study*, Lumberjack RC&D, USDA Forest Service National Fire Plan
[15] B. Rummer, 2007, *Harvesting and Transportation of Forest Biomass*, US Forest Service
[16] Y. Suzuki, Y. Hatano, S. Murakami, T. Okazawa, S. Sagayama, J. Gotou, T. Ichihar K. Miyoshi, *Harvesting and Transportation of Logging Residue Logs Accumulated Along Road Side for Woody Biomass Plant in a Local Community*, Council on Forest Engineering (COFE) Conference Proceedings: "Environmentally Sound Forest Operations"
[17] P. Tsioras, 2010, *Perspectives of the forest workers in Greece*, iForest (2010) 3: 118-123
[18] M. Vonk, *Harvest of logging residues in the Netherlands*, Probos: Institute for Forestry, Forest Products and Services
[19] J. Raitila, 2008, *Firewood production and business models*, VTT
[20] K. Kärhä, A. Jouhiaho, 2009, *Producing chopped firewood with firewood processors*, Biomass and Bioenergy, vol. 33, Iss. 9

II. WOOD BIOMASS PRODUCTION IN SMALL SCALE FORESTS (SSF)

Prepared by: Tine Premrl, dr. Nike Krajnc, (SFI)

A. INTRODUCTION

The substitution of biomass for fossil fuels in energy consumption is a measure to mitigate global warming, as well as having other advantages. Political action plans for increased use exist at both European and national levels (14). Reaching these targets is possible with larger mobilisation of biomass from forests.

In Europe, private forest owners have a crucial role in achieving sustainable forest management in sustaining the productivity of forests and in satisfying the increasing demand for wood resources from wood processing manufacturers and bioenergy producers. In the EU 49.6 % of forest and other wooded land is privately owned. However, the ownership structure varies greatly among countries (20).

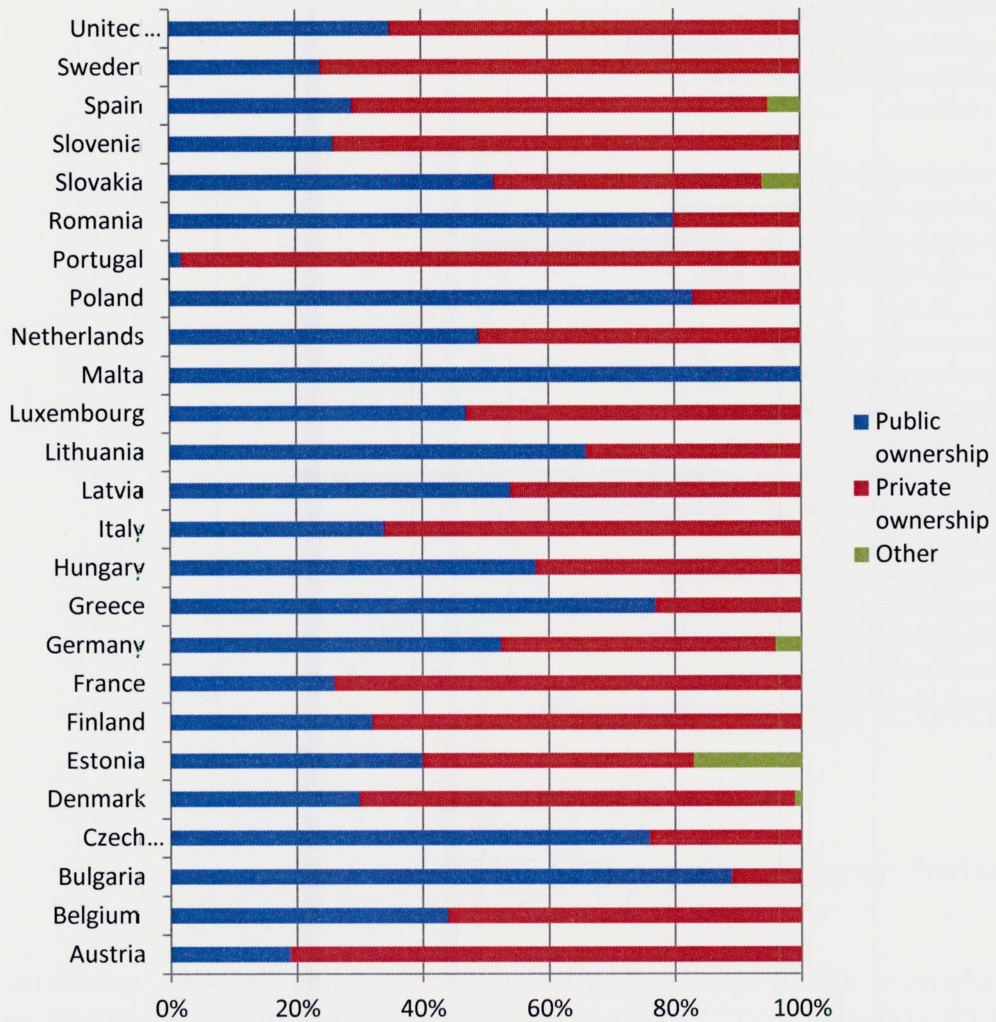


FIGURE 20: Forest ownership in EU (FRA 2010)

Question is what small-scale forest ownership (SCFO) means and how production of wood biomass is organize in SCFO. Are SCFO important for wood biomass production chain and how they are different from other forest owners? Here we can also mention another expression non-industrial forest owner (NIPF) which is close to SCFO meaning as word family forest also is.

B. FOREST AND FORESTRY IN EUROPE

The second most common type of land use in Europe is forestry. Forests and other wooded land cover 42% of the land area and are one of the most valuable multifunctional and renewable natural assets we have. The most densely forested Member States are Finland, Sweden and Slovenia, whereas the least forested are Malta, Ireland and the Netherlands.

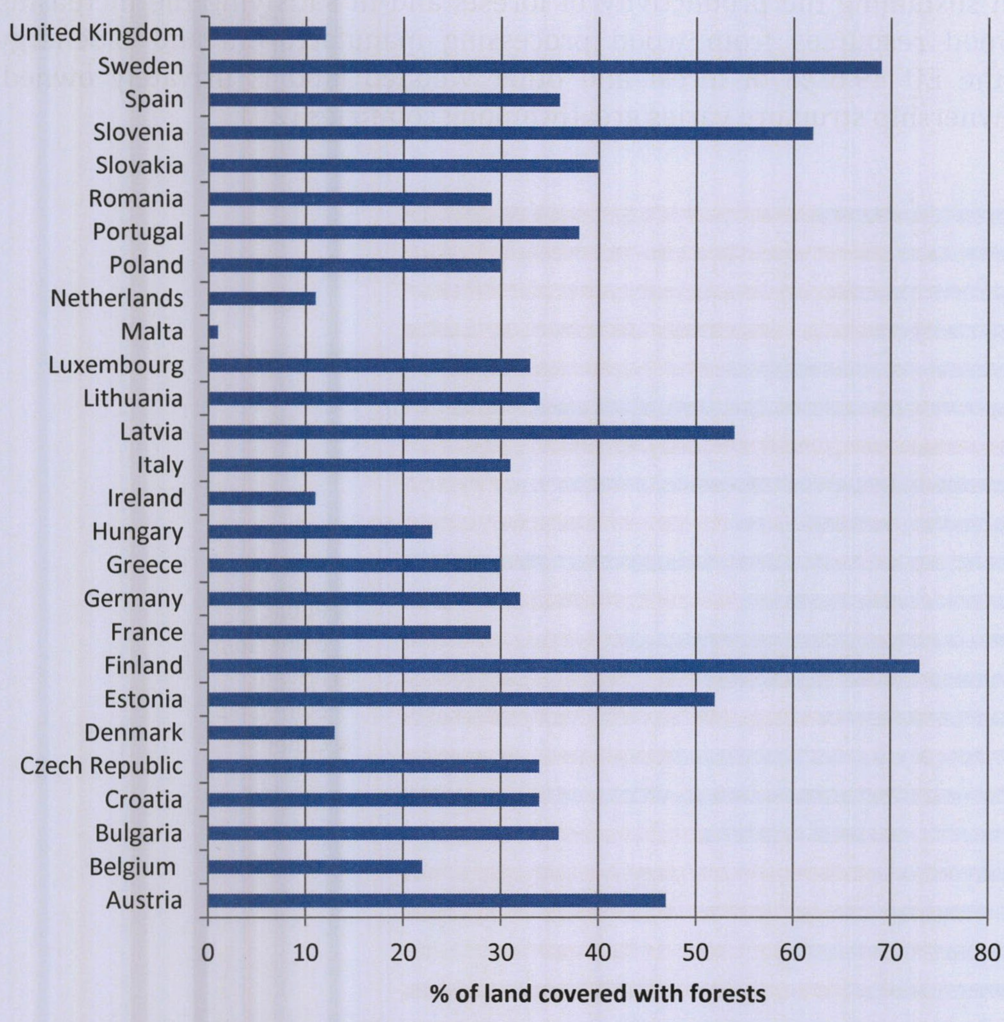


Figure 21: Share of land covered with forests (FRA 2005)

We can make economic use of this asset without compromising its other functions; indeed, the area covered by forests continues to increase due to efforts on the part of forest services to maintain it, increase it by afforestation and harvest wood from forests available for wood supply in a sustainable manner. Only 60 % of the net annual increment in forests available for wood supply is currently harvested in the EU. This suggests that a certain increase in wood demand could be accommodated without negatively affecting the EU forests. (1)

In some Central and Eastern European countries the number of smallholdings has increased as a result of restitution and privatization. Holdings smaller than 6 ha represent 70 percent of the total area of private holdings in Poland and 40 percent in Slovenia, but only 5 percent in Hungary, where holdings larger than 100 ha represent over 45 percent. At the overall European level, the number of smallholdings is vast. In number, almost three-quarters of all private holdings are less than 3 ha. At the same time, holdings smaller than 3 ha account only 7 percent of the area, of privately held forest in the 11 countries that has reported these data. (20)

C. SMALL SCALE FORESTS – WHAT IS IT?

A 50 % of European forests have been in the hands of about 16 million family forest owners for many generations. They manage their properties balancing economic, ecological and social values, with a strong personal attachment and commitment to the forest, inherited through the generations. They management goals can also by different as national targets what is present as under or unmanaged forest.

More expressions or keywords are used to describe this kind of private ownership. In the literature key words as family forests, non-industrial private forest owners, small scale forest owners can be found and connecting also with status of forest owners, non-agriculture forest owners, non residential forest owners.

The concept of small-scale forest ownership means different things to different people in different countries. Traditionally, within Europe, many small-scale forest owners were economically dependent on their forests, either for home or commercial use, usually linked with farming activities. However, many small-scale forest owners are no longer economically dependent on their forests and these owners appear to increasingly focus their management on amenity functions rather than on production functions or they abandon management of their property.

Talking about small scale forestry is often talking about forest management styles and their preferences normally not so connected to economic behaviour logic connected with harvesting of theirs forest potentials and maximizing economic preferences. Such kind of management style is often described as under management or non management by institutions following the goal of forest utilization in the frame of forest management plans.

About 30% of the forest owners have an indifferent attitude to their forests. Almost 40% of the forest owners are only modestly interested in forest management; often they have an environmental management orientation. Only one-third of the private forest owners are still economically dependent on their forests; they have predominantly a multifunctional management orientation. Policies to stimulate forestry development should be diversified in respect to these different types of small-scale forest owners (19).

Forest size is one of the factors which define SSFO the median forest size varies in Europe between 1.3 ha in Greece to 4.5 ha in Spain.

D. WOOD BIOMASS AND FOREST POLICY

Renewable sources of energy include wind, solar, hydro-electric and tidal power, geothermal energy and biomass (including wood). Their use reduces dependence on fossil fuel markets, is generally carbon neutral and often diversifies energy supply.

In 2009, the EU adopted a Directive (2009/28/EC) on the promotion of the use of energy from renewable sources, while the Europe 2020 strategy from 2010 confirmed an EU target such that 20 % of energy should come from renewable sources by 2020 In 2010, the European Commission published a paper (COM(2010)11) on sustainability requirements for the use of biomass in electricity, heating and cooling, promoting the sustainable production and use of biomass, as well as an internal market in biomass trade.

The potential woody biomass supply for the period 2010–2030 from stemwood, residues, stumps and other biomass was estimated at 744 million m^3 yr^{-1} overbark in 2010 and could range from 623 to 895 million m^3 yr^{-1} overbark in 2030, depending on the mobilisation scenario. These potentials represented 50–71% of the theoretical potential. Constraints thus significantly reduced the biomass potentials that could be mobilised. Soil productivity appeared to be an important environmental factor when considering the increased use of biomass from forests. Also the attitude of private forest owners towards increased use of forest biomass can have an important effect.

The analysis showed that it is possible to increase the availability of forest biomass significantly beyond the current level of resource utilisation. Implementing these ambitious scenarios would imply quite drastic changes in forest resource management across Europe (18).

This policy also effect on the forest and their owners. New business opportunities rise up for rural areas with biomass. Value of wood for biomass increase, local market and regional market has developed and forest owners have a chance to contribute from and to this market.

E. SMALL SCALE FOREST OWNERS' MANAGEMENT GOALS

Forest owners make up a very heterogeneous population. About 30% of the forest owners have an indifferent attitude to their forests. This group includes many absentee owners and retired local owners, who own only forest lands but who are not economically dependent on these forests. Almost 40% of the forest owners are only modestly interested in forest management; often they have an environmental management orientation. This group includes many hobby owners and part-time employed people. Only one-third of the private forest owners are still economically dependent on their forests; they have predominantly a multifunctional management orientation. (7)

In the research (8) about innovation and entrepreneurship in forestry in Central Europe that majority of forest owners irrespective of the holding size are not managing their forests to increase the profit but mainly to maintain forest as a capital.

There is a general concern for loss in soil fertility due to wood fuel harvesting which is why some owners do not sell forest fuels. Two types of fuel-selling forest owners appear:

1) an active manager seeking different gains from wood fuel harvest,
2) an owner who primarily relies on the advice of the timber buyer.

The findings indicate that large-scale traders of wood fuels have to be active in increasing supply, making direct contact with forest owners, and connecting trade with information on ecological and silvicultural effects. Offering ash recycling may enhance supply more than marginal price increases.
Policies to stimulate forestry development are searching for tools to full fill target of forest policy in SSF. It is hard to say that only one tool can contribute to the goals. Tools should be diversified in respect to these different types of small-scale forest owners. (6)

F. WOOD BIOMASS AND ITS USE ON SSF

Private households were generally the main users of wood as a source of energy, accounting for almost half (47.5 %) of the wood used for energy purposes in 2007 across the ten Member States.

Firewood is society's oldest source of household energy and is still extensively used around the world also technologically advanced countries with high energy consumption and can affect available biomass resources. Majority of firewood users are satisfied with their energy source and are not thinking to abandon it. Researchers found out that half (53%) of the firewood producing households owned forest and thereby had free access to wood. The use of firewood is suggested to influence decisions of private forest owners about management and harvest of forest biomass, and, thus, affect supply for bioenergy and other uses (15). Small scale firewood business run by small scale forest owners is largely present in EU member state countries. This marked is often unorganized and uncontrolled.
Wood chips are more resent type of wood biomass which is largely use for large energy users as CHP plants, district heating systems or bigger individual users. SSF meets wood chips production on different levels:

- First level is a forest owner as an owner of wood biomass which can be potentially used for wood chips production.
- Second forest owner as a producer of wood chips who is producing wood chips from his own wood biomass or he is buying wood biomass on the market.
- Third as forest owner who is using wood chips for producing energy for his own needs, or selling it through energy contracting model.

Inclusion of forest fuel used for domestic consumption should probably be included as a reason for not selling forest fuels. Other factors who explain forest owners' decision to sell or not to sell wood biomass are transaction costs, soil fertility concerns, silviculture aspects and feedback. The fifth dimension, economic concerns, does not appear to be a strong indicator less than half of the forest owner sees a price as factor to influence their decision to sell or not to sell wood biomass. The primary reason for selling wood fuel was that the harvesting operation cleared the ground of debris (11).

Any way it came up that additional market, wood energy market has influence on raise of stumping prices and that forest owners don't have second thoughts to sell their wood for energy use instead of traditional industry use (10).

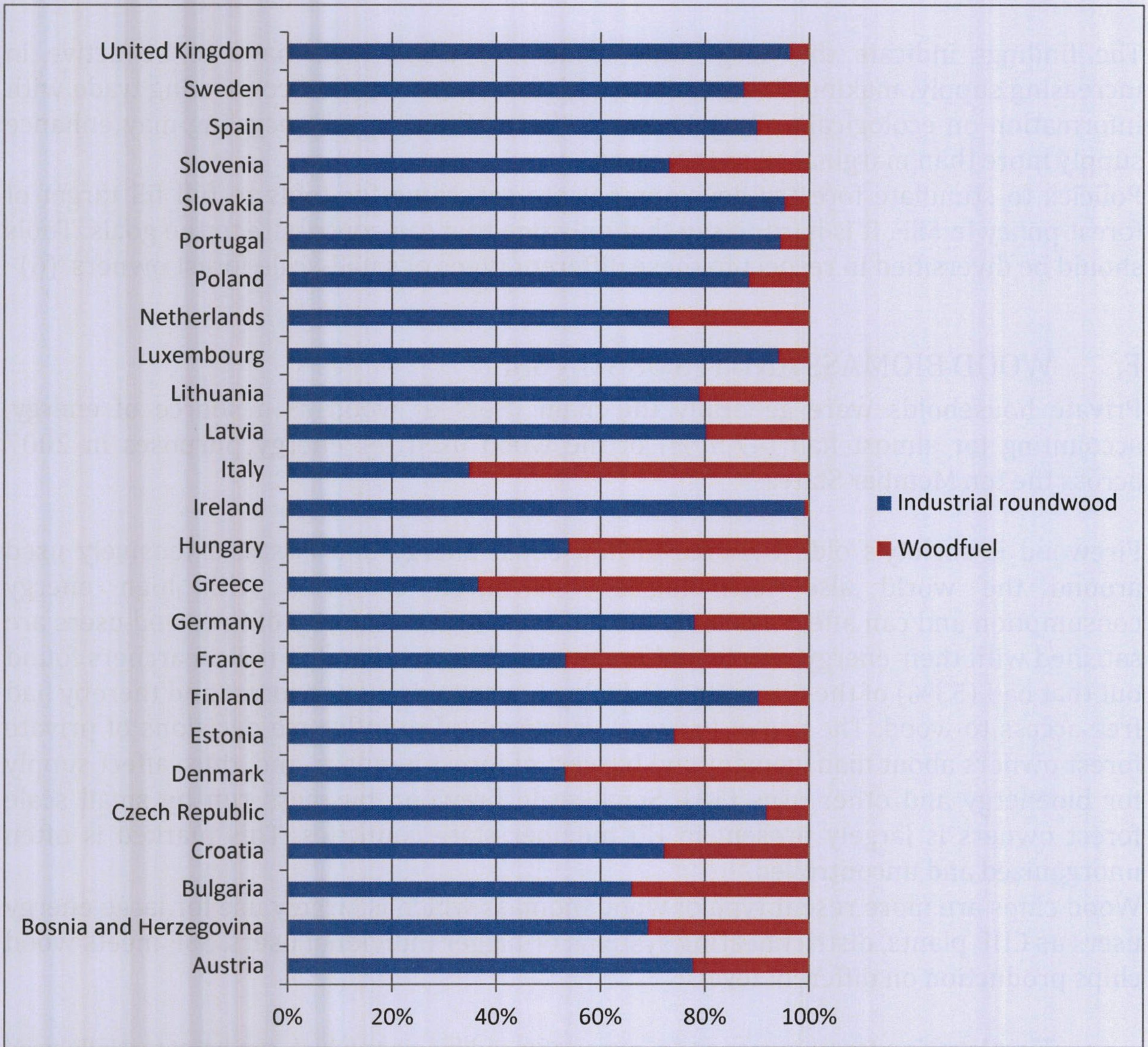


FIGURE 22: Structure of wood products in 2005 (FRA 2010)

Around 4 million people are employed in forestry and wood processing industry. These people mostly live in rural areas. Forests and forestry are the backbones of keeping these areas inhabited. They contribute significantly to the economic and social sustainability of these communities. Family forestry provides employment and income and contributes to the strengthening of less developed regions in Europe.

G. FOREST OWNERS ASSOTIATIONS

Forms of cooperation and resulting activities vary, ranging from low levels of commitment for purposes of information/education, to more structured participation for financial and marketing purposes. Likewise, the origins of cooperation differ from country to country, though common elements emerge (e.g. the role of government, reaction to a stimulus or threat). (12)

Associating forest owners is not a 'traditional' policy instrument and it is an answer on policy tools which do not achieve forest policy objective sufficiently. Because of this, governments start to stimulating cooperation among forest owners. Better results are

coming out on the fields of forest utilization, safety, multifunctional of forest management... (9)
Forest owners associations and cooperation are known in all EU while best practices examples or higher level of cooperation is known from Scandinavian countries and Austria. Forest owners associations have also common EU umbrella in Confederation of European Forest Owners in Brussels.
Forest owners associations can be organize on different level. It can be association were only information are exchanging and education events are organizes, or it can be more business orientated. In business orientated associations you can have more levels from common wood trading to common management of forests and from selling a wood on stump to selling more final wood products or energy.

H. WOOD BIOMASS PRODUCTION

When talking about wood fuel harvesting we should have in mind two different technologies. Fist deals with wood logs production and the second with wood chips production. All two technologies are already implemented also in small scale forestry and biomass production.

Traditional wood logs were prepared as 1 m long logs which could be spitted or not already at production side, at forest road side or at terminal. They were stored and seasoned in stacks. Nowadays wood logs are cut in 25-40 cm long pieces using different types of wood splitters and crosscutters. These machines can be divided in three main groups: crosscutting devices, splitting devices and crosscutting – splitting devices.
Depending on the operation, machines for log woods production can be distinguished into:

- <u>crosscutting devices</u>: if based on band saw, they can process diameters bigger than 40 cm and have low cutting loss; if based on disc saw, they can only process smaller diameters and have higher cutting loss;
- <u>splitting devices</u>: they are equipped with either a wedge or a screw breaking device. The ones with wedge device for domestic use have either 2 or 4 sides, they work keeping the log vertical and can exert up to 15 t of splitting power, while for industrial use the log is kept horizontal and pushed against a wedge, or a grid, up to 16 sides with a power up to 40 – 60 t. The ones with screw are equipped with a threaded cone which spins into the wood so as to split it; they are faster than the former, but less precise; for safety reasons, the best solution is to install the device on a boom (of a tractor, for example);

- crosscutting – splitting devices: there are mobile models, but most of them are stationary machines which combine the two operations, allowing an elevated process automation and a higher productivity, working both on logs and on big branches. They are endowed with electric or spark-ignition engine (up to 55 kW), can work logs up to 6 m long and 60 cm of diameter and can produce more than 12 t/h of material.

Processing hardwood requires more power than processing softwood and all types of wood can more easily be split when fresh rather than seasoned.

A **chipper** is a machine that is especially built to reduce wood to chips and can either be stationary or mounted on a carriage, on a trailer, on a truck or on the rear three point hitch of a tractor. It can be equipped with its own engine or driven by the tractor power. Depending on the chipping unit, it is possible to differentiate between:

- **disc chippers**: the chipping unit consists of a heavy flywheel on which are radial mounted from two to four knives. The material comes into contact with the disc at an angle of 30 to 40 degrees to the plane of the disc and the rotating knives, acting against an anvil at the end of the inffed spout, cut progressive slices from the wood that breaks up into chips whilst being cut. Chip size is usually between 0.3 and 4.5 cm and can be modified by an adjustable bed knife;

- **drum chippers**: bigger and more powerful than disc chippers, these chippers can easily work both logs and harvesting residues. The chipping unit consists of a steel cylinder with up to 12 knives installed in tangential position; chip size is more heterogeneous, with lengths up to 6.5 cm. Knives must be replaced every 50–100 t (working with hardwood) or 200–300 t (with softwood);

- **feed screw chippers**: chipping is provided by a big worm of decreasing section with sharp edges that rotates on a horizontal axis. These machines, which are not particularly widespread, can mostly process full trees or logs and produce bigger chips (up to 8 cm) compared to disc and drum chippers.

According to the required power, three categories can be identified:

- **small power**: usually installed on the rear three point hitch of a tractor or on a trailer, these chippers are powered by the tractor power or by an independent engine (~50 kW). They can only process small diameters (20 cm max) and can produce no more than 20 t/day;

- **medium power**: trailer-mounted, usually with independent engine (50-110 kW), they can chip diameters up to 30 cm and produce up to 50 t/day;

- **high power**: installed on trailers or on trucks, these chippers are sometimes activated by the truck's engine, but normally they are provided with an autonomous engine (>130 kW); they can chip big diameters (>30 cm) and easily produce more than 60 t/day.

The **sieve** is an important tool which makes possible the selection of chips during the expulsion phase, thus refining the material but at the same time lowering productivity.
When chipping is performed in a place different from the final plant, chips are transported either by truck or truck and trailer, rarely by articulated vehicle, set up with large cases in light alloy; a clamshell bucket loader can be installed on the truck and trailer to make possible an autonomous loading of the chips.
The investment in wood chipper depend on many parameters like source of power (tractor, diesel engine, truck,...), way of fid-in of row material, conveyors, splitter (for large diameter logs), ... The analysis showed that the investments is in close correlation with productivity of wood chipper.

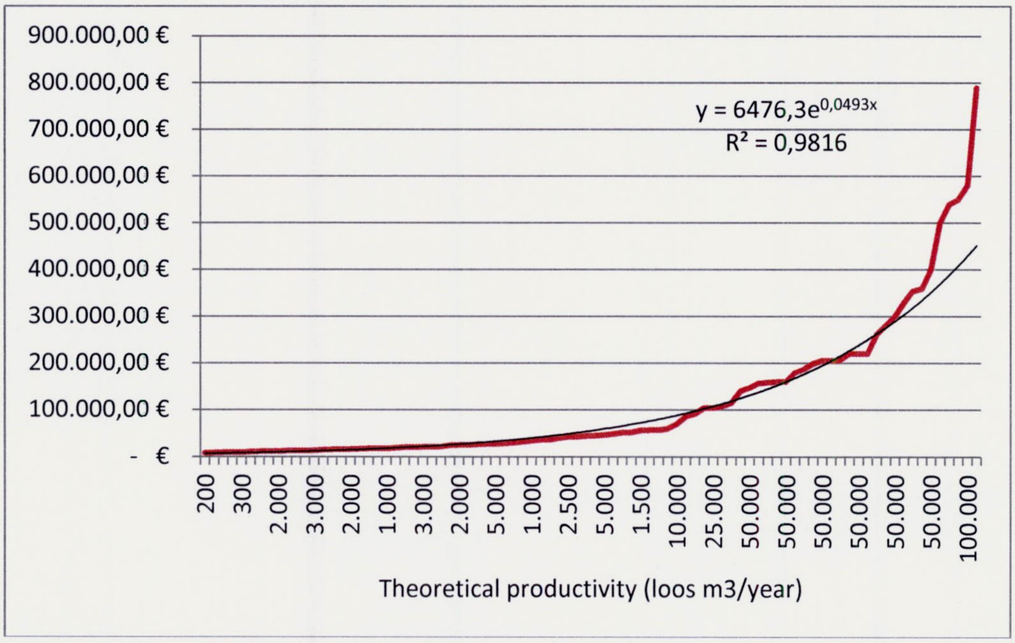


FIGURE 23: Correlation between theoretical productivity of wood chipper and investment

The investment costs are also in close correlation to power requirement. But this correlation is not as high as in the case of productivity. The main reason for that is the energy source which can be a tractor, independent engine (diesel or electric) or truck. The investment costs are the highest in the case of chippers powered by track.

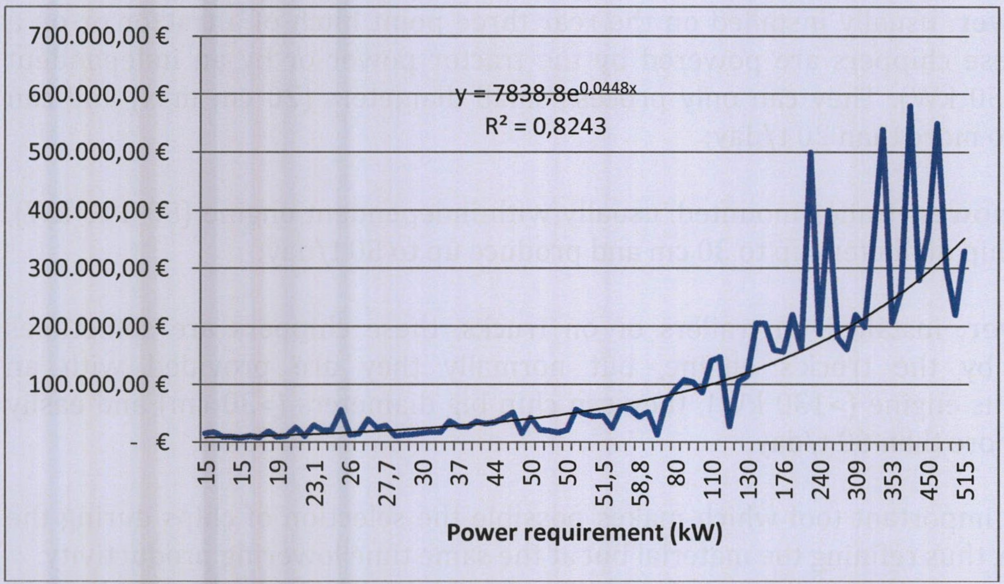


Figure 24: Correlation between theoretical productivity of wood chipper and investment

I. WOOD-ENERGY SUPPLY CHAINS

As an example, three charts of possible wood-energy supply chains for chip boilers (with fixed or mobile sieve) situated in mountainous area have been provided below. Calculations have been done from the point of view of the forest enterprise that manages the supply chain (22).[1]

1. **Thinning in coniferous stand** adopting the FTS working system. Chip destination: chip boiler with fixed sieve (M 30%, P45; ref. table 4.4.1). Price ex thermal power station 18-20 €/bulk m³ (= 80-90 €/t).

Working phase	Equipment	Productivity (bulk m³/h)	Cost (€/bulk m³)
Felling	2 chainsaws	35	0.5
Full tree skidding	2 tractors and winch	17	5.9
Mechanized processing at the landing site	processor on tractor	24.3	1.4
Loading logs on the truck and trailer	truck and trailer	121.5	0.6
Transporting logs to the biomass trade centre (back&forth 90 km)	truck and trailer	36.5	2
Unloading logs from the truck and trailer	truck and trailer	145.8	0.5
Natural seasoning	—	—	0.3
Chipping logs	high power chipper	100	1.4
Delivery of chips (back&forth 90 km)	truck and trailer	26.4 *	2
TOTAL			14.6
Standing tree value is to be added to the total (from 0 to 5 €/bulk m³ for thinning operations)			
*seasoned chips (M 30%)			

2. **Main felling in coniferous stand** adopting the FTS working system. Chip destination: chip boiler with mobile sieve (M 55%, P63; ref. table 4.4.1). Price ex thermal power station 10-13 €/bulk m³ (= 29-38 €/t). Harvesting residues let on the forest road are available at no cost, since all harvesting costs are charged on industrial timber.

[1] The following equivalences have been employed: 1 solid m³=2.43 bulk m³ of chips (volume coefficient=0.41 solid m³/bulk m³); 1 bulk m³=223 kg (M 30%); 1 bulk m³=347 kg (M 55%).

Working phase	Equipment	Productivity (bulk m³/h)	Cost (€/bulk m³)
Chipping harvesting residues	high power chipper	55	2.6
Delivery of chips (back&forth 90 km)	truck and trailer	22.1 *	2.4
TOTAL			5
* fresh chips (M 55%)			

3. **Thinning in coniferous stand** adopting the FTS working system. Chip destination: chip boiler with mobile sieve (M 55%, P63). Price ex thermal power station 10-13 €/bulk m³ (= 29-38 €/t). The results are in agreement with indications found in the reviewed literature, according to which harvesting chances with fresh chips (from softwoods or hardwoods) as the only product, to be employed in boilers with mobile sieve, can hardly be economically feasible. The production of this kind of chips must be integrative, and not exclusive, of the harvesting chance.

Working phase	Equipment	Productivity (bulk m³/h)	Cost (€/bulk m³)
Felling	2 chainsaws	35	0.5
Full tree skidding	2 tractors and winch	17	5.9
Chipping full trees	high power chipper	60	2.4
Delivery of chips (back&forth 90 km)	truck and trailer	22.1 *	2.4
TOTAL			11.2
Standing tree value is to be added to the total (from 0 to 5 €/bulk m³ for thinning operations)			
*fresh chips (M 55%)			

EXSAMPLES OF FOREST ENERGY BUSINESS MODELS

a) CHIPPING AND SHREDDING/GRINDING AND TRANSPORT
Wood biomass transported to terminals (larger storage places) where wood chips are produced and sold to end users

- Companies are specialized in using terminal-sized machines or effective chippers (larger size)
- Based on contract work
- Transport often provided

b) CHIPPING AND TRANSPORT

- Companies are specialized in chipping and transporting of chips
- Customers are heating plants and organizations supplying fuel for plants

c) (BUYING) + HARVESTING + CHIPPING + TRANSPORT

- Specialized in harvesting, chipping and transporting energy wood

d) (BUYING) + HARVESTING + CHIPPING + TRANSPORT + PRODUCTION AND SUPPLY OF HEAT

- Turnkey basis = management of the whole value chain
- Heating entrepreneurship

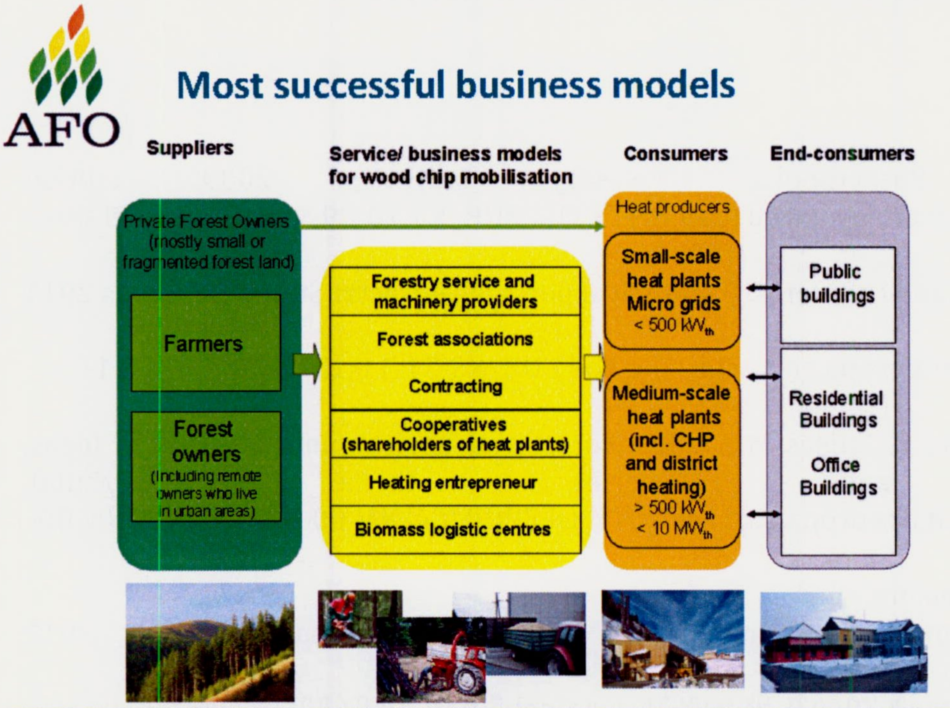


FIGURE 25: Example of one business model prepared in the frame of AFO project

J. CONCLUSION

For the SSFO we can say that important variations in the nature of the ownership and management of small-scale forests are present across Europe.
Traditionally, within Europe, many small-scale forest owners were economically dependent on their forests, either for home or commercial use, but this situation is changing. Non economical management preferences are rising up and abandon of forests in one hand is present while on the other growing demand for wood and wood for energy is rising.
Experiences are showing that associating forest owners brings results. Their forests are better managed and more wood is coming on the marked. Wood buyers approach to the forest owners biomass is becoming more difficult as forest owners are economically not depended from forest or have others management goals which can be in conflict with wood biomass utilisation.
Majority part of forest owners who are heating their homes with wood gets its wood from their forest. Self consumption and local level wood biomass trading is present in their forest management goals.

Parts of the forest owners have also more entrepreneur spirit and they are producing wood biomass (firewood and wood chips) in larger scale.

Wood biomass business with practical positive results is business of forest owners associations and cooperations. Cooperation among forest owners is needed if they want to fulfil demands of end users in wood energy contracting model or in biomass trade centres.

As environment policy is coming important and governments want reach RES targets wood biomass is getting higher value which makes it more profitable.

Better price is stimulating wood biomass utilization and fostering wood biomass market what results also in employment and can contribute to RDP goals.

K. References

1. Eurostat Pocketbooks, Forestry statistic, 2009 edition http://epp.eurostat.ec.europa.eu/cache/ITY_OFFPUB/KS-78-09-993/EN/KS-78-09-993-EN.PDF
2. Forestry in the EU and the world: A statistical portrait, eurostat Statistical books 2011 edition http://epp.eurostat.ec.europa.eu/cache/ITY_OFFPUB/KS-31-11-137/EN/KS-31-11-137-EN.PDF
3. Zanatta Y., Mikkola E, Engles M., 2000, Forest and environment Statistic in focus, Agriculture and fisheries, theme 5-17/2000, http://epp.eurostat.ec.europa.eu/cache/ITY_OFFPUB/CA-NN-00-017/EN/CA-NN-00-017-EN.PDF
4. http://www.cepf-eu.org
5. CEPF position on the sustainability of forest based biomass, Brussels, 2011 http://www.cepf-eu.org/vedl/Position%20on%20the%20sustainability%20of%20forest%20biomass.pdf
6. K. Freerk Wiersum, Birgit H.M. Elands and Marjanke A. Hoogstra, (2005) Small-Scale Forest Ownership across Europe: Characteristics and Future Potential. Small-scale Forestry Economics, Management and Policy, 4 (1): 1-19,2005.
7. Wood fuel supply as a function of forest owner preferences and management styles Original Research Article Biomass and Bioenergy, Volume 22, Issue 4, April 2002, Pages 237-249 Folke Bohlin, Anders Roos http://www.sciencedirect.com/science?_ob=MiamiImageURL&_cid=271477&_user=4776866&_pii=S0961953402000028&_check=y&_origin=search&_zone=rslt_list_item&_coverDate=2002-04-30&wchp=dGLzVlk-zSkzk&md5=e29a8e56846b2fbb63f2c5216e33444e/1-s2.0-S0961953402000028-main.pdf
8. Kuuluvainen J, Karppinen H, Ovaskalainen V. Land owner objectives and non-industrial private timber supply. Forest Science 1996;42:300–9.
9. Van Gossum, P., S. Luyssaert, et al. (2005). "Forest groups as support to private forest owners in developing close-to-nature management." Forest Policy and Economics 7(4): 589-601.
10. Conrad Iv, J. L., M. C. Bolding, et al. (2010). "Wood-to-energy expansion, forest ownership changes, and mill closure: Consequences for U.S. South's wood supply chain." Forest Policy and Economics 12(6): 399-406.

11. Bohlin, F. and A. Roos (2002). "Wood fuel supply as a function of forest owner preferences and management styles." Biomass and Bioenergy 22(4): 237-249.
12. David B, K. (2005). "The cooperation of private forest owners on scales larger than one individual property: international examples and potential application in the United States." Forest Policy and Economics 7(4): 671-688.
13. Glück, P., M. Avdibegović, et al. (2010). "The preconditions for the formation of private forest owners' interest associations in the Western Balkan Region." Forest Policy and Economics 12(4): 250-263.
14. Stupak, I., N. Clarke, et al. (2007). "Sustainable use of forest biomass for energy: Proceedings of the WOOD-EN-MAN Session at the Conference Nordic Bioenergy 2005 Trondheim, Norway, 27 October 2005." Biomass and Bioenergy 31(10): 665.
15. Ola, L. (2011). "Residential use of firewood in Northern Sweden and its influence on forest biomass resources." Biomass and Bioenergy 35(1): 385-390.
16. Van Gossum, P., S. Luyssaert, et al. (2005). "Forest groups as support to private forest owners in developing close-to-nature management." Forest Policy and Economics 7(4): 589-601.
17 Markowski-Lindsay, M., T. Stevens, et al. (2012). "Family forest owner preferences for biomass harvesting in Massachusetts." Forest Policy and Economics 14(1): 127-135.
18 Verkerk, P. J., P. Anttila, et al. (2011). "The realisable potential supply of woody biomass from forests in the European Union." Forest Ecology and Management 261(11): 2007-2015.
19. Wiersum, K., B. Elands, et al. (2005). "Small-scale forest ownership across Europe: Characteristics and future potential." Small-Scale Forestry 4(1): 1-19.
20. F. Hirsch, A. Korotkov and M. Wilnhammer Private forest ownership in Europe http://www.fao.org/docrep/010/a1346e/a1346e06.htm
21. http://www.fao.org/forestry/fra/fra2010/en/
22. Francescato, v., et al. (2009). "Wood fuels handbook". AIEL, www.biomasstradecentres.eu

III. DIFFERENT ASPECTS OF WOOD BIOMASS PRODUCTION FROM SHORT ROTATION PLANTATIONS

Prepared by: Loibnegger Thomas and Metschina Christian (Lk Stmk)

A. SHORT ROTATION CROPLAND AREAS IN AUSTRIA

The land areas used for cultivating the coppice crops intended for energy generation have grown considerably in recent years, despite the fact that the areas actually put into production have fallen significantly short of expectations. Of late, the market for energy wood has seen a significant increase in demand. Many of the heating plants placed into operation during the past few years have struggled with energy wood supply problems, and it is becoming increasingly difficult to procure such supplies since the sawmill industry now tends to make greater use of its scrap wood (e.g. pellet production or generating heat to dry wood) instead of selling it on to third parties. To provide sustainable relief for the existing forest areas, part of the future demand for wood must be addressed through short rotation. The hope is that short rotation areas will grow by 15,000 hectares by 2020. Such expansion would make it possible to supply some 3.5 petajoules of raw energy through biomass (by comparison, Austria's gross domestic energy consumption is approximately 1,400 petajoules).

In order to meet future goals for the increase of short rotation croplands, however, more information regarding energy wood cultivation is needed. At present, particular attention is being paid to the optimisation of harvesting and logistics techniques. The logistics management of biomass represents an essential cost factor. Therefore, optimised harvesting and transport logistics represent an important means to ensure the competitiveness and thus widespread use of short rotation forestry in the future.

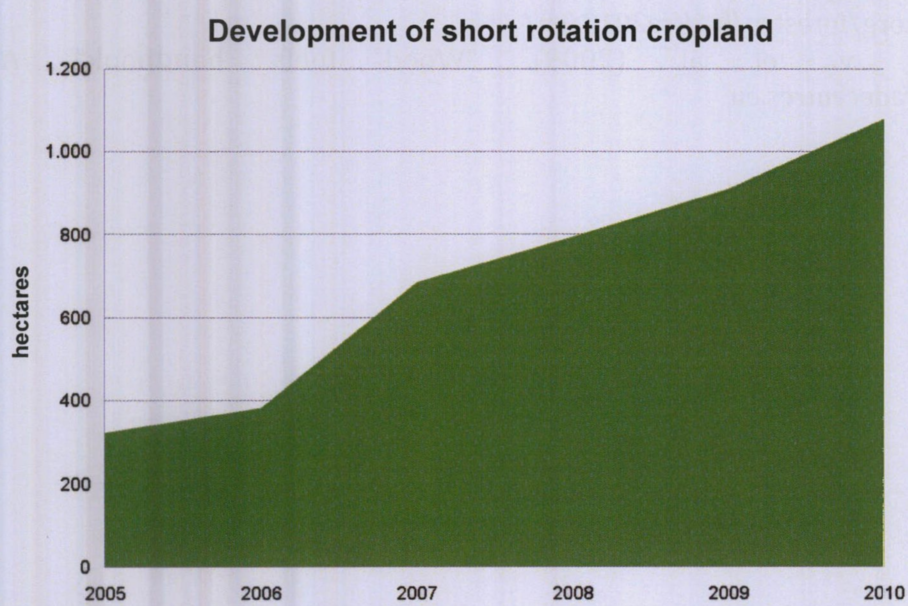


FIGURE 26: *DEVELOPMENT OF SHORT ROTATION CROPLAND IN AUSTRIA*

B. HARVESTING TECHNIQUES

Harvesting takes place in the dormant period of vegetation, typically between November and March, since plants contain the least amount of water during the period after their leaves fall. Harvesting during the foliated period reduces the vitality of blossoming and, in the worst-case scenario, can even kill the plant. To avoid damaging the soil, the ground should be relatively easy to drive on and preferably frozen.

Selection of the appropriate harvesting method is linked directly to the desired end product and indirectly to the length of the rotation period. This relationship demands that the harvesting technique be chosen even before the cultivation area is laid out! *With respect to short rotation cropland, the following harvesting techniques have proven feasible in Austria:*

1. *MOTOR-MANUAL HARVESTING (USING MOTORISED HAND TOOLS)*

This harvesting technique is highly labour intensive and is especially suitable for poplars with multiannual rotation periods (rotation period greater than 5 years) on difficult terrain and on croplands structured into small-scale land parcels. The trunks are cut close to the ground by a team of two workers using a power saw, and the timber is then transported to the storage area using a trailer and loading crane or tractor equipped with a front loader. The power saw operator cuts down the tree while the second worker uses a log grapple to guide the trunks in the desired fall direction. After cutting, the trunks must be moved to a sunny area to dry for at least 6 to 8 months, which prevents them from interfering with the growth of new shoots. After being stored in piles during the summer months, the trunks are processed into chips during the autumn with mobile wood chippers. Storing the trunks during the summer reduces water content to nearly 25%, which amounts to a 50% reduction. Besides largely obviating the need for expensive harvesting machines, this method economises on drying and storage costs. Where steep or rugged terrain is involved, motor-manual harvesting is much less costly than using a harvester. Where the rotation period is 10 years, any quality timber components that have accumulated can be hauled away from the cultivation area separately, as they can be used as raw materials for downstream production.

FIGURE 27: ***MOTOR-MANUAL HARVESTING***

2. *SINGLE-STAGE, FULLY MECHANISED HARVESTING SYSTEM*

The single-stage, fully mechanised system represents the harvesting method most commonly used today. Here, the wood is cut at the base of the trees and reduced to chips in a single operation. In practice, it has proven effective to equip a Claas Jaguar silage harvester with a wood cutting header instead of a corn header. It should be noted, however, that this fully mechanised harvesting system is appropriate only for short rotation periods (2–3 years) since the cutting diameter cannot exceed 12 to 14 centimetres. Considering a maximum working width of about 1.2 m, for example, rows of poplars spaced at intervals of 2.8 m or a double row of willows (with between-row spacing of 0.75 m) can be harvested in a single operation. The advantages of this integrated system are that it allows fast, powerful, inexpensive and labour-extensive harvesting; however, it is unsuitable for use on sloped areas.

The following factors should be taken into account when using silage harvesters:

- On cultivated areas of less than one hectare, the working hours required - and thus the costs of chipping per ton of dry harvested wood chips - increases disproportionately since the turning time and time spent transporting equipment also increases disproportionately.
- Uniform stocks of high-yield trees are a prerequisite for efficient use of the wood chipper. Uneven stocks that contain gaps increase harvesting costs since individual thick-trunked trees situated along the edges of gaps impact the harvesting time of the entire cultivated area.
- Excessively narrow turnrow areas (less than 7 m) increase the amount of work involved and costs per dry weight harvested.
- Driving across tree stumps damages the stumps and vehicle tyres.
- Especially for trailers, the use of wide tyres is necessary to protect the soil.
- In mechanical weed control, it is important to avoid piling up the rows and pushing rocks onto them since doing so damages the chipper attachment blades.
- In the case of willows, double rows must be spaced at intervals of no less than 1.5 m; otherwise, the adjacent rows will be run over by the wheels of the harvester.
- Weeds are no problem for the harvester but they reduce the quality of the wood chips. Since snow accumulates on weeds, this increases the percentage of snow in the wood chips when harvesting is carried out during snowy weather.
- Where poplars are concerned, as of the second harvest, the number of trunks is greater than during the first harvest. This reduces average trunk diameter and facilitates harvesting with the silage harvester.
- Willow clones with shallow, long projecting shoots can cause problems in subsequent harvests since the shoots cannot be gathered properly by the attachment or because neighbouring rows may be run over by the harvester.
- Using the silage harvester on steep hillsides may cause problems during the intake process.
- The wood chips generated have a dry matter content of about 45%, which corresponds to a medium-fine grade chip size.

FIGURE 28: *FULLY MECHANISED HARVESTING SYSTEM*

3. *FORESTRY HARVESTING METHODS*

Where longer rotation periods and large diameters are concerned, such as in the paper, board and furniture industries, the use of conventional forestry equipment, such as harvesters or combined felling and baling machines, is typical. After felling, the harvested material is baled, stored on the edge of the field and – if not used as whole timber in the furniture industry – is processed into chips after an interim storage period using mobile or stationary heavy-duty chippers.

Compared to the single-stage, fully mechanised harvesting system, this technique is significantly more expensive per unit weight of harvested wood. The efficiency of forestry harvesting methods increases proportionally with the diameter of the tree trunks. Thus, the ideal rotation periods are 10 years or longer.

FIGURE 29: *HARVESTER*

4. *SYSTEMS CURRENTLY IN THE DEVELOPMENT STAGE*

Harvesting systems oriented to rotation periods of 2 to 4 years, which fell the trees and place them on vehicles that transport them to the edge of the field for stacking, are in the initial stage of market introduction. After a drying period, the wood is usually processed into chips during the autumn using a heavy-duty wood chipper. Tractor-trailers, bulk materials vehicles or container trucks are used to haul away the wood chips.

C. YIELDS FROM SHORT ROTATION CROPS

Short rotation crop yield varies according to location and variety. For example, higher peak yields can be obtained with poplars compared to willows, albeit in favourable environments. In the first harvest, however, yields from willows exceed those of poplars because of the higher number of plants. As noted previously, poplars can grow significantly as of the second harvest by branching out with up to 3 to 4 thick shoots per stump. Generally, the yield level depends less on mechanisation than on the variety, number of plants per hectare, soil composition, water supply, average annual temperature and the intensity of cultivation measures. Proper management – essentially, doing the right things at the right time – has a pronounced effect on yield levels and thus on the success of the short rotation operation.

Yield is generally expressed in terms of oven-dry tons (ODT) where oven-dry means zero per cent moisture content per hectare per year (ODT/ha/a). Expressing production in terms of dry substance per year enables comparison with food crops (e.g. corn) and is therefore a popular reference value. Volumetric units such as m^3 or loose cubic metres (LCM) vary widely according to chip size and cultivation type, which means they cannot be understood readily without knowing the actual water content. Multiannual rotation periods have a higher density in terms of kilograms per loose cubic metre. This is because the bark accounts for a smaller percentage of the total material, and growth rings are spaced closer together due to slightly slower growth. Here, bulk weight varies from 280 to 350 kg per solid cubic metre.

Willow and poplar yields per hectare per year

Variety	Marginal yield location	Favourable location	Optimal location
Poplar	7-10 ODT	12-15 ODT	16-25 ODT
Willow	7-12 ODT	12-14 ODT	15-25 ODT
	In fresh condition just after harvesting, this corresponds to approximate volumes of ...		
	45-60 LCM	60-90 LCM	90-120 LCM

FIGURE 30: ***WILLOW AND POPLAR YIELDS PER HECTARE PER YEAR***

1. ENERGY YIELD FROM SHORT ROTATION WOOD

Compared to forest wood, short rotation wood generally has a higher percentage of bark and thus a higher percentage of mineral components. The higher mineral content reduces overall calorific value and leads to higher ash content when burned. Seasoned wood chips from short rotation forestry have a calorific value of 3.8 kWh/kg while the calorific value of freshly harvested wood chips approaches 1.8 kWh/kg. In contrast, wood chips from forests have a calorific value of 4.2 kWh/kg when seasoned and a calorific value of 2.5 kWh/kg when freshly harvested. To prevent significant loss of efficiency during burning, the wood chips must be dried.

Energy yield data

Poplar (2-year rotation)		Yield level		
		Marginal yield	Favourable location	Optimal location
Yield	ODT/ha/a	10	16	20
Energy yield	kWh/ha	49,300	78,900	98,600
Heating oil equivalent	l/ha	4,900	7,830	9,780
CO_2-reduction	kg/ha	14,700	23,500	29,400

FIGURE 31: *ENERGY YIELD DATA*

D. LOGISTICS CONCEPTS

The logistics involved with wood chip production are challenging from both the organisational and the economic standpoint. Depending on the size and shape of the cultivated area and the level of yield, the self-propelled silage harvester can produce from 100 to 250 loose cubic metres of wood chips per hour; however, that volume must be transported to the buyer as cost effectively as possible *and* without volume losses. *Four different logistics chains have generally proved effective for wood chip transport:*

1. DIRECT TRANSPORT WITH TRACTOR-TRAILER (OPTION 1)

For short distances, direct transport of the wood chips from the field to the heating plant is the most cost-effective solution. The bulk density of the wood chips is roughly equal to 250 to 350 kilograms of freshly harvested chips per loose cubic metre, a volume that approaches the bulk density of corn. As a result, dump or ejector trailers are used for such transport just as they are for transporting corn. At full chipping capacity and assuming a distance of 5 km, for example, seven dump trailers (19 m^3) or four ejector trailers (35 m^3) will be necessary. Smaller trailers cause a significant increase in the amount of work involved but may be equivalent to ejector trailers in terms of cost when considering short transport distances, lower yields or small cultivated areas. In all variations, vehicles driving over the field should be equipped with large volume tyres inflated appropriately to prevent long-term soil damage.

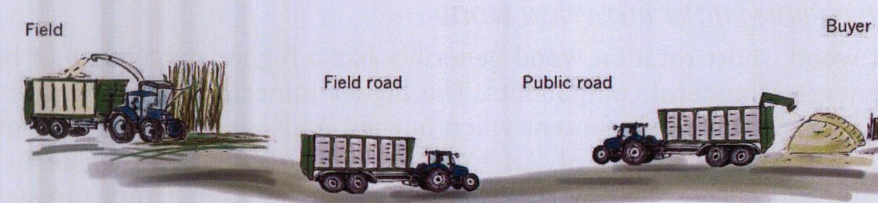


FIGURE 32: ***LOGISTIC CHAIN WITH TRACTOR-TRAILER***

2. TRANSPORT WITH INTERMEDIATE STORAGE SITE AND BULK MATERIALS TRUCK (OPTION 2)

At distances that exceed 8 to 15 km, it may be economically advantageous to cross load the chips from farming trailers to a bulk materials truck (70 m^3 – 90 m^3 capacity). Cross loading the wood chips requires an intermediate storage site (asphalted or paved surface to minimise rock and dirt infiltration) as well as a wheel loader or telescopic loader. The intermediate storage site acts as a buffer and separates the transportation modes that move wood chips from the field to the intermediate storage site from those used to transport wood chips from the intermediate storage site to the heating plant. For optimal use of the intermediate storage site, a loader is needed to pile the wood chips.

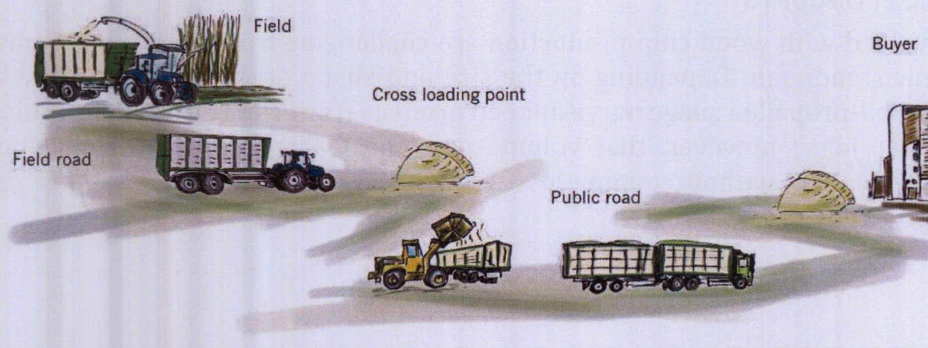


FIGURE 33: ***LOGISTIC CHAIN WITH NTERMEDIATE STORAGE SITE AND BULK MATERIALS TRUCK***

3. TRANSPORT WITH INTERMEDIATE STORAGE SITE AND HOOKLIFT TRAILER (OPTION 3)

Tractor-trailers that serve as prime movers for containers can be used as an alternative to bulk materials trucks. Tractor-driven hooklift trailers are used to fill 35 m^3 containers with the wood harvested by the silage harvester. When depositing the filled container, a sufficiently large, paved area is needed to ensure that the containers can be reinstalled easily for further transport. To minimise wait time, a sufficient number of containers must remain available. These act as a buffer by separating the work of the silage harvester from truck transport. As long as a sufficient number of hooklift trailers and containers are available, container transport tends to be less costly than using a bulk materials truck (option 2).

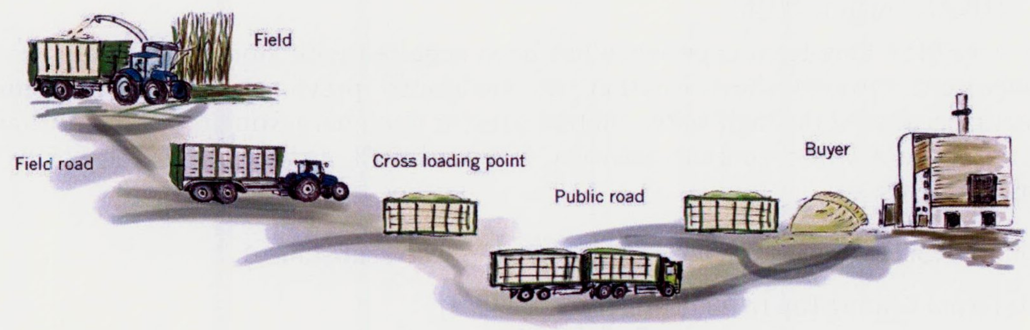


FIGURE 34: ***LOGISTIC CHAIN WITH INTERMEDIATE STORAGE SITE AND HOOKLIFT TRAILER***

4. *TRANSPORT WITH SPECIAL CROSS LOADING VEHICLES (OPTION 4)*

A cross loading vehicle can be used instead of an ejector trailer to transport the wood chips from the field to the bulk materials truck. To minimise wait time on site, a bulk materials truck must be available constantly for cross loading. If not, the silage harvester's output per unit area is reduced. Direct cross loading does not require an intermediate storage site or wheeled loader, but the investment costs for the cross loading vehicles are relatively high.

FIGURE 35: ***SPECIAL CROSS LOADING VEHICLES***

Approximate transport cost (excluding VAT)

	5 km	15 km	25 km
Option 1	EUR 1-1.6 /per LCM	EUR 2.2-2.6 /per LCM	EUR 3.3-4.6 /per LCM
Option 2		EUR 2.2-2.6 /per LCM	EUR 2.6-3/ /per LCM
Option 3		EUR 1.8-2.5 /per LCM	EUR 2.3-2.9 /per LCM
Option 4		EUR 2.3-3.3 /per LCM	EUR 3-3.6 /per LCM

FIGURE 36: ***TRANSPORT COSTS IN EURO PER LOSS CUBIC METRE (LCM)***

E. STORAGE AND DRYING

To date, very little long-term experience has been acquired with storage techniques for wood chips harvested through short rotation. As mentioned previously, wood chip storage is problematic because of the high water content present upon harvesting. Since freshly harvested wood chips have a water content between 45% and 60%, immediate storage leads to the following problems:

- Mould formation (health hazard; loss of energy and substance)
- Internal heating (up to 60 degrees; fire hazard)
- Rot (loss of energy and volume of up to 25% per year)
- Greater storage space required (lower energy density)

It is impossible to use moist harvested material for heat generation in private or agricultural applications. If the wood chips cannot be used directly in industrial-sized furnaces (e.g. in heating plants or combined heating and power stations), then drying is an absolute necessity. Long-term storage and incineration in small furnaces is only possible if the water content does not exceed 25% to 30%.

Artificial drying, i.e. technical drying by means of mechanical air dryers is justifiable in terms of energy and costs only if surplus heat, such as heat from biogas facilities, can be used for that purpose. Where outdoor storage is concerned, a tarpaulin cover is the most inexpensive alternative, but higher losses of volume must be taken into account. In practical applications, drying can also be accomplished in open, roofed storage spaces that are well ventilated on all sides. Using this approach, fresh wood chips can achieve a water content of 25% in 2 to 3 months. In multiannual rotation periods, the harvested trunks can be dried naturally during the summer months in sunny areas that are exposed to the wind. Additionally, the use of solar-based drying methods and renewable energies can be combined. Here, the wood chips are spread over a sloped, grated deck, and air heated by solar collectors is blown through the layer of chips from below the grate. The heated air can absorb much more water than the ambient air, which accelerates the drying process.

1. WASTE HEAT RECOVERY FROM BIOGAS STATIONS

When drying moist short rotation wood chips, the heat produced by existing biogas stations is especially suitable. Specific experiences with this drying method have already been documented by the Lower Austrian Chamber of Agriculture. Through the drying process, the thermal energy of a biogas plant is stored in the wood chips. A reduction in water content from 50% to 15% increases the energy content from 2.5 kWh/kg to 4.5 kWh/kg. In practice, dryer trailers or drying booths are used for the drying process. The dryer trailer has a capacity of 5 to 50 loose cubic metres and can dry wood chips with 50% water content to a level of less than 10%, irrespective of chip size. The cost associated with such drying ranges from EUR 3.0 to EUR 5.0 per loose cubic metre. From a capacity standpoint, the drying booth can hold about three times the amount of wood chips as a dryer trailer. Vertical augers provide better agitation and thus more uniform drying of the wood chips. The final water content of the wood chips can be reduced to 6%.

Beyond avoiding the problems outlined above, wood chip drying offers the following advantages:

- Increased energy density
- Greater range of use for short rotation wood chips gathered from rotation periods of 2 to 3 years (e.g. for heat generation in small furnaces)
- Wood chip production is possible year-round, regardless of the time of harvesting
- Approximately 15% reduction in the storage area required
- Extended boiler operating life and increased system efficiency
- Decreased transport costs through weight reduction

FIGURE 37: ***TRAILER FOR WOOD CHIP DRYING AND DOCKING SYSTEM FOR FEEDING CHIPS INTO THE DRYING BOOTH (WENNINGER BIOGAS PLANT, LOWER AUSTRIA)***

IV. SOCIO-ECONOMIC IMPACTS OF BIOENERGY PRODUCTION

Prepared by: Velimir Šegon and dr. Julije Domac (REGEA)

Biomass production and utilisation, bioenergy technologies, their market share, and research interests in these issues vary considerably between different countries and even within different regions of the same country. Nevertheless, in most of the countries socio-economic benefits of bioenergy use can clearly be identified as a significant driving force in increasing the share of bioenergy in the total energy supply. In most countries regional employment created and economic gains are probably the two most important issues regarding biomass use for energy production.

The essence of sustainability of bioenergy projects from a social aspect is how they are perceived by society, and how different societies benefit from this activity. Avoiding carbon emissions, environment protection, security of energy supply on a national level or other 'big issues' are for local communities an added bonus, but the primary driving force are much more likely employment or job creation, contribution to regional economy and income improvement. Consequently, such benefits will result in increased social cohesion and stability that stem from the introduction of an employment and income generating source.

Socio-economic impact studies are commonly used to evaluate the local, regional and/or national implications of implementing particular development decisions. Typically, these implications are measured in terms of economic indices, such as employment and monetary gains, but in effect the analysis relates to a number of aspects, which include social, cultural and environmental issues. The problem lies in the fact that these latter elements are not always tractable to quantitative analysis and, therefore, have been precluded from the majority of impact assessments in the past, even though at the local level they may be very significant. In reality, local socio-economic impacts are diverse and will differ according to such factors as the nature of the technology, local economic structures, social profiles and production processes.

In many ways the social implications arising from local bioenergy investment represents the '*woolly*' end of impact studies. Nevertheless, they can be broken down into two categories:

- those relating to an increased standard of living;
- those that contribute to increased social cohesion and stability.

In economic terms the 'standard of living' refers to a household's consumption level, or its level of monetary income. However, other factors contribute to a person's standard of living but which have no immediate economic value. These include such factors as education, the surrounding environment and healthcare, and, accordingly, they should be given equal consideration.

The introduction of a net employment and income-generating source, such as bioenergy production, could help to stem adverse social and cohesion trends (e.g., high levels of unemployment, rural depopulation, etc.). It is evident that rural areas in some countries are suffering from significant levels of outward migration, which mitigates against population stability. Given bioenergy's propensity for rural locations, the deployment of bioenergy plants may have positive effects upon rural labour markets by, firstly, introducing direct employment and, secondly, by supporting related industries and the employment therein (e.g., the farming community and local/regional renewable energy technology providers, installers and service providers).

In that regard, the strict distinction between social and economic impacts and benefits of a bioenergy project is in most cases not possible and such an analysis would provide only partial results at best. A summary of some of the socio-economic impacts associated with local bioenergy production is listed in Table 1. (Domac et al., 2005)

Dimension	Benefit
Social Aspects	• Increased Standard of Living - Environment - Health - Education • Social Cohesion and Stability - Migration effects (mitigating rural depopulation) - Regional development - Rural diversification
Macro Level	• Security of Supply / Risk Diversification • Regional Growth • Reduced Regional Trade Balance • Export Potential
Supply Side	• Increased Productivity • Enhanced Competitiveness • Labour and Population Mobility (induced effects) • Improved Infrastructure
Demand Side	• Employment • Income and Wealth Creation • Induced Investment • Support of Related Industries

TABLE 4: IMPACTS ASSOCIATED WITH LOCAL BIOENERGY PRODUCTION

The specified impacts represent a general overview of possible criteria which could be included in the sustainability aspects of biomass resource assessments from the socio-economic point of view. However, the definition of specific socio-economic criteria to be included in the analysis is dependent from the particular project and its background.

A short elaboration of some specific aspects regarding socio-economic sustainability issues is provided in the following text:

- Competition with the demand for food, feed and fibers

  As the area globally available for agriculture is restricted, an expansion of biomass cultivation inevitably leads to an increased competition – above all with food production. There is a consensus that food security has to be given priority. The domestic food demand depends on two aspects – population growth and dietary preferences (i. e. the share of meat). Also the level of self-sufficiency needs to be considered – at least in studies on European and national level. Theoretically, all food needed in Europe could be imported which would free all agricultural land within Europe for biomass production. However, it has to be taken into account that importing food likely leads to indirect land use changes in other countries: If food production on existing (and restricted) agricultural land is not given priority the production of energy crops will lead to a displacement of food production to non-agricultural land – where land use changes of natural or semi-natural ecosystems might be caused. The same can of course happen in Europe if food production is not given priority and if the conversion of forest or grassland is not strictly excluded. These land use changes are to be seen as critical from a climate change and biodiversity point of view.

Although it is discussed less fiercely, there is also a strong competition for biomass used for the production of biomaterials such as wood as building material. Also this demand should be given priority as biomass currently is the only alternative source whereas for energy, other renewable sources are available such as solar or hydro power.

However, the final decision on the priorities regarding competition for food, feed and fibers and to what extent this decision should be left to the free market is within the responsibilities of different national governments (respecting of course international agreements). In that regard, this criterion should be applied at the global level and consequently bioenergy, food and biomaterials would be produced where it is economically most profitable.

- Creation of new employment (especially in rural areas)

  The introduction of a net employment and income-generating source, such as bioenergy production, could help to stem adverse social and cohesion trends (e.g., high levels of unemployment, rural depopulation, etc.). It is evident that rural areas in some countries are suffering from significant levels of outward migration, which mitigates against population stability. Given bioenergy's propensity for rural locations, the deployment of bioenergy plants may have positive effects upon rural labour markets by, firstly, introducing direct employment and, secondly, by supporting related industries and the employment therein (e.g., the farming community and local/regional renewable energy technology providers, installers and service providers).

- Increased Standard of Living

  In economic terms the 'standard of living' refers to a household's consumption level, or its level of monetary income. However, other factors contribute to a person's standard of living but which have no immediate economic value. These include such factors as education, the surrounding environment and healthcare, and, accordingly, they should be given equal consideration.

- Landscape and visibility of the countryside

  The introduction of short rotation coppice (SRC) often creates new and visible features on the countryside. It can have aither a beneficial or negative impact on the landscape, depending on where and how it is grown. The actual impact will depend upon the character and quality of the recipient landscape, the extent of physical change involved, and the ability of the landscape to accommodate this change.

There is a variety of different approaches and methodologies used to integrate socio-economic criteria in the overall assessment framework of bioenergy use. A commonly used methodology is the Multi Criteria Analysis (MCA), which has been widely applied in the bioenergy related fields during the past 15 years. Generally, MCA is concerned with the establishment of an adequate framework for the evaluation of a specific project through taking into consideration a number of different factors. These factors comprise technical, economic, social, and environmental criteria and MCA is typically applied to compare several different project options (for example using renewable and conventional energy sources to meet the energy demand). However, the specific techniques and tools to apply the MCA methodology are quite varied and based on the selected tool different results can be obtained (Buchholz at al., 2008).

Other approaches include the development of individual tools and methodologies focused on the assessment of socio-economic interaction with specific aspects of bioenergy such as biodiversity (Haberl at al., 2009), rural land use change (Haughton at al., 2009) and others.

The common feature of all methodologies regarding the inclusion of socio-economic issues is the necessity to obtain extensive feedback from local stakeholders, usually through the organisation of several workshops, round tables and other similar meetings through the various project implementation stages. This information is afterwards structured into appropriate assessment criteria, which can be used to analyse the potential impacts but also to estimate the bioenergy potential from the socio-economic point of view.

V. ENVIRONMENTAL ASPECTS OF WOOD BIOMASS PRODUCTION

Prepared by: Dr. Johann Kremer(TUM)

In addition to technical and economic aspects of the supply chains due to an increasing importance of energy wood on the fuel markets in the last 15 years, **environmental aspects** come to be in the spotlight.

Dominant topics are the **nutrient removal** and the emerging risk of soil degradation, the risk of depletion as well as the **Energy- and Carbon footprints** of fuel supply. Beside these topics, aspects of **soil protection and conservation** have to be considered as in every other wood harvesting operation.

Nutrient removal due to energy-wood harvesting is one of the major problems pointed out by MEIWES et al. (2008), ETTL et al. (2007), KÖLLING and STETTER (2008), RÖSER et al. (2008) and WITTKOPF (2005) in their scientific work. Wood and other biomass extracted by forest operations always do cause a withdrawal of carbon and nutrients from the forest. Special emphasis has to be given to the nutrient-elements potassium, calcium, magnesium and nitrogen. The stockpile of those elements in forest soils depends of the type of parental rock material, former land use or manuring and the soil acidification due to air pollutants. Within the compartments of a tree as are trunk, branches, needles/leaves and bark the nutrients occur in different concentrations. Whilst the logwood is quite poor of nutrients, the concentration increases in bark and brushwood. The highest nutrient amount is to be found in needles and leaves (RASPE et al., 1999). As concerning biomass-export, this means that the nutrient loss will not follow a linear pattern according to the intensity of cutting (biomass extracted). MEIWES et al. (2008) found out that the **surplus in yield** fore whole tree harvesting (complete overground biomass excluding roots and stump) compared to stem wood (debarked log) harvesting is only reaching a factor of 1,2. On the other hand the loss of nutrient elements like potassium, calcium and magnesium is raising to a factor of 3,0. The authors conclude that the mobilzation of potential biomass including compartments (branches, leaves, needles) which were not interesting in the past, will cause a higher impact to the nutrient pool then expected looking only at the biomass profits (MEIWES et al., 2008). WITTKOPF (2005) made some calculations concerning the effect in yield when extracting whole trees and found out that depending of the tree species 24 to 28 % more biomass is extracted than in normal cuttings and thinnings. On closer inspection one has to take into account the age of the stands as well as **harvesting losses**. Whilst in younger stands (close to 20 years) the rate of yield can improve up to 80 % in older ones (80 years and more) it only reaches around 25 %. In a case study within a 100 years old spruce stand (extraction rate 118 cubic meters/ha) he calculated a rate of yield loss of 14 %. However losses are subject to a great variation depending on the harvesting technic, processing and the stand aspect as well.

At the moment there is lots of work going on for a bunch of practical information material concerning the estimation of the effects of different cutting intensities towards nutrient balance. One is expecting advice how to act and treate stands, avoiding to high depletion risks. In Bavaria at the LWF (bavarian state institute for forestry) there are discussions about the developement of „traffic-light"-maps as decision support for the extraction intensity (assortments, and amount of biomass) which guarantee easy to handle assistence tools for foresters and forest owners (KÖLLING und STETTER, 2008). The colors red, yellow and green symbolize whether there is a possibility for a sustainable use at a low, moderate or high intensity of biomass extraction. BÖTTCHER (2010) is working on a decision support system which breaks-down the former idea to the level of forest sites and gives information about the possibilities for sustainable biomass use having regard to the nutrient pool sustainability. Related to scenario calculations of the forest yield simulator SILVA (KLEMMT et al., 2004) developed at the chair of forest yield science of the technical university Munich in the future, treatments and options for wood harvesting operations can be tested against their response and reaction to nutrient removal and forest yield.

In the near future there will be a need to verify not only directives for usage restrictions but also possibilities of a recycling management. This should be able to restore the nutrient pool oft he forest ecosystem by introducing **wood ashes** for exemple in the **shape of pellets**. According to (RÖSER et al., 2008 in) scandinavian countries this attempt is allready in a testing stage. At the moment main restrictions are to be found in the properties of nutrient elements of the wood-ashes as well as in the fizico-chemical degradation behavior after turnout. On the other hand the actual fotrest legislation and the fertlizer regulation in Germany are restrictive and do not allow any turnout (SCHÄFFER, 2002). The LfU-leaflet *„Verwertung und Beseitigung von Holzaschen"* gives an overview of legal framework requirements and the possibilities for the recycling of different wood ashes (LFU, 2009).

Fundamental basics for **product-related ecological balances** on forestry production and different wood products are to be found in ZIMMER & WEGENER (1996; 2001) and WEGENER et al. (1997; 2004). Lots of studies have been performed in the field of ecological assessment of energy supply from wood fuels. The papers are focusing mainly on boilers and plants or on products like wood-pellets (ZIMMER, 2009). There are no papers giving good data and analysis about supply chaines from forests to customers and end-consumers.

MÄLKKI et al. (2001) ran a study in Finland on the basis of a **Life-Cycle-Assessment** dealing with the ecological aspects of the utilization forest residues. Two processing lines were compared – wood chipping in the stand against wood chipping on the forest road – each with and without stacked stocking. The outcome was that the primary energy input for harvesting, chipping and transport amounts to around 2,3 to 3,2 % of the included usable Energy within the chipped material. These findings were confirmed by ZIMMER (2009) who found out that the primary energy input is varying within a range between **1,4 % to 6,5 %** of the usable Energy of the wood chips, depending on the processing option, degree of mechanization and assortment of the chipping good.

He proved that, increasing mechanization at a reasonable degree of capacity utilization causes increasing technical productivity. This means that an energy input on a lower level per functional unit has to be invested in the sistem. From the point of view of energy balance one could speak of a principle „ecology follows econopmy". A theoretical example depicts the meening of the principle:

- the transport of fresh chips with a skidder/trailer of 15 m^3 capacity over a distance of 100 km means a primary energy input of 10 to 15 % of the usable energy of the wood chips. (this option makes no sense from the economical point of view of course, but it serves for a theoretical comparison)

- A modern efficient transport medium as a push floor truck with a capacity of 90 m^3 will need only a primary energy input of 1,5 % of the usable energy of the wood chips over the same distance (ZIMMER, 2009).

A quite recent life cycle assesment concerning the production of chips on short rotation plantations was performed by RÖDL (2008). One important outcome is that the primary energy input for the production of one tonne of bulk chips is of 136 MJ when no fertilizer is used and with a fertilizer treatment it amounts to 361 MJ. Compared to the lower heating value of 18 MJ/kg dry matter, the energy input is only around 0,76 to 2,01 % oft he intrinsic energy of the wood chips. The plot respectively the energy plantation is setting the system boundaries in this study as the transportation costs tot he heating plant are not included. Anyhow, comparing the published statements of ZIMMER (2009) with regard to forest wood chips, the concern that the energy input on short rotation plantations will be much higher because of the site preparation by ploughing, harrowing and weed control, turned out to be unfounded. RÖDL (2008) is giving evidence on **carbon release values** related to cultivation, maintainance and harvesting of short rotation plantations. The values are to be found in a range of 12 to 22 kg of carbon dioxid for one tonne of bulk wood chips. At the same time the cultivation of wood in short rotation plantations is causing a withdrawel of the green-house gas carbon dioxid from the atmosphere by fixing it within the wood at an amount of 1.851 kg per tonne of wood chips.

In this context we have to emphasize that, when drawing the carbon balance we have to take into account a **substitution effect** due to the conversion from fossile to renewable energy sources. Introducing the use of forest wood chips, fossil fuels are substituted and their emissions will not pollute the atmosphere any more (ZIMMER, 2009). Therefore we have to give credit to renewables in the balance. The figures should ammount the carbon dioxide quantity which is released at the total oxidation of the intrinsic carbon of fuel oil equivalents.

The same calculation routine has to be performed when dealing with material utilization of wood, because there is also a substitution of other materials, which in most of the cases originate from fossile resources. ZIMMER (2009) points out that the energy substitution and the effects on the carbon balances at the moment are not a subject in the current discussions about climate change.

Due to their enormous importance the long term carbon storage potentials as well as the substitution effects have to be taken into consideration when discussions in the framework of the area of conflict **material** versus **energetic use** of wood are occuring.

A. References

BÖTTCHER, M. (2010):
Entscheidungsstützungssystem zum Nährstoffentzug bei der Holzernte. Vortrag im Rahmen des Seminar „Forstliches Versuchswesen" des Lehrstuhls für Waldwachstumskunde der TU München. Freising, 11.01.2010.

ETTL, R.; WEIS; W.; GÖTTLEIN, W. (2007):
Holz verbrennt, Asche bleibt. Konsequenzen für die stoffliche Nachhaltigkeit der Waldbewirtschaftung in Bayern. AFZ - Der Wald, Heft 2, S. 74 - 77.

KLEMMT, H-J.; BIBER, P.; PRETZSCH, H. (2004):
Mit SILVA in die Zukunft des Waldes blicken. LWFaktuell Nr. 46, Seite 38-40.

KLOOS, W. (2010):
Kurzumtriebsgehölze als Teil der Biomassestrategie der Bundesregierung. Bundesministerium für Ernährung, Landwirtschaft und Verbraucherschutz (BMELV). Vortragsunterlagen des Symposiums Agrarholz 2010 am 18./19.05.2010 in Berlin.

KÖLLING, C.; STETTER, U. (2008):
Holzasche - Abfall oder Rohstoff? LWFaktuell Nr. 63, S. 54-56.

LFU (2009):
Merkblatt - Verwertung und Beseitigung von Holzaschen. Herausgegeben vom Bayerischen Landesamt für Umwelt. Erstellt von den Bayerischen Landesanstalten für Landwirtschaft (LfL) und Wald und Forstwirtschaft (LWF). 18 S.

MÄLKKI, H.; HARJU,T.; VIRTANEN, Y. (2001):
Life cycle assessment of logging-residue-based energy. Pp. 92-107 in RICHARDSON, J.; BJÖRHEDEN, R.; HAKKILA, P.; LOWE, A.T.; SMITH, C.T.: Bioenergy from Sustainable Forestry: Principles and Practice. Proceedings of IEA Bioenergy Task 18 Workshop, 16-20 October 2000, Coffs Harbour, New South Wales, Australia. New Zealand Forest Research Institute, Forest Research Bulletin No. 223.

MATTHIES, D.; KREMER, J. (1999):
Bodenmechanische und bodenphysikalische Ergebnisse im Rahmen eines „Informationssystems zum bodenverträglichen Forstmaschineneinsatz". Forsttechnische Informationen Nr. 5+6/1999. S. 44-49.

MEIWES, K. J.; ASCHE, N.; BLOCK, J.; KALLWEIT, R.; KÖLLING, C.; RABEN, G.; v. WILPERT, K. (2008):
Potenziale und Restriktionen der Biomassenutzung im Wald. AFZ-Der Wald 10-11/2008, S. 598-603.

RÖDL, S. (2008):
Ökobilanzierung der Holzproduktion im Kurzumtrieb. Arbeitsbericht des Instituts für Ökonomie der Forst- und Holzwirtschaft 2008 / 3. 90 S.

RÖSER, D.; ASIKAINEN, A.; RAULUND-RASMUSSEN, K.; STUPAK, I. (2008):
Sustainable Use of forest biomass for energy. A synthesis with focus on the Baltic and Nordic region. Managing Forest Ecosystems, Vol. 12. Published by Springer. Dordrecht. The Netherlands. ISBN 978-1-4020-5053-4. 262 p.

SCHÄFFER, J. (2002):
Meliorationswirkung und ökosystemare Risiken von Holzascheausbringung auf Waldböden Südwestdeutschlands. Berichte Freiburger Forstliche Forschung 43, S. 39 - 51.

SCHAFFER, E.; PICHLER, H.; SCHOPFHAUSER, W.; PÖLZL, T. (2010):
BioBereit Manual. Kooperationsabkommen Forst-Holz-Papier (FHP). Download unter http://www.forstholzpapier.at/data_list.php?App=Downloads&Channel=3&mItem=Downloads.

WEGENER, G.; ZIMMER, B.; BERGER, G.; SCHEIBENPFLUG, B. (2004):
Analyse der Transportketten von Holz, Holzwerkstoffen und Restholzsortimenten als Grundlage für produktbezogene Ökobilanzen. Abschlussbericht, Bonn: Holzabsatzfonds; 37 S.

ZIMMER, B.; WEGENER, G. (1996):
Stoff- und Energieflüsse vom Forst zum Sägewerk. Holz Roh Werkst. 54, 4: 217-223.

ZIMMER, B.; WEGENER, G. (2001):
Ökobilanzierung: Methode zur Quantifizierung der Kohlenstoff-Speicherpotenziale von

Holzprodukten über deren Lebensweg In: Schulte, A. et al. (Hrsg.): Weltforstwirtschaft nach Kyoto: Wald und Holz als Kohlenstoffspeicher und regenerativer Energieträger. Aachen: Shaker Vlg. ISBN 3-8265-8641-7; S. 149-163.

ZIMMER, B. (2009):
Ökobilanzierung der Bereitstellung von Waldhackschnitzeln. In EBERHARDINGER, A.; WARKOTSCH, W.; ZORMAIER, F.; SCHARDT, M.; HUBER, T.; ZIMMER, B. (2009): Prozessanalyse und Ökobilanzierung der Bereitstellung von Waldhackgut. Schlussbericht. Lehrstuhl für Forstliche Arbeitswissenschaft und Angewandte Informatik der TU München. Freising, 2009. 165 S.

ZORMAIER, F.; SCHARDT, M.; HUBER, T. (2009):
IST-Analyse und Stärken-Schwächen-Analyse der Bereitstellung von Waldhackgut zur thermischen Verwertung. LWF Bayern. In EBERHARDINGER, A.; WARKOTSCH, W.; ZORMAIER, F.; SCHARDT, M.; HUBER, T.; ZIMMER, B. (2009): Prozessanalyse und Ökobilanzierung der Bereitstellung von Waldhackgut. Schlussbericht. Lehrstuhl für Forstliche Arbeitswissenschaft und Angewandte Informatik der TU München. Freising, 2009. 165 S.

VI. DIFFERENT ASPECTS OF FOREST RESIDUE USE

Prepared by: Noel Gavigan (IrBEA)

A. INTRODUCTION

Clearfelling operations have traditionally concentrated on producing saw log for the timber industry, logging residues (crowns, branches and foliage) are generally discarded despite constituting anywhere from 15-40%[1] of the entire mass of the standing tree. A large portion of this material can be collected and utilised as biomass fuel. Residue collection operations are being carried out all across Europe to varying degrees, the methods used vary from region to region and largely depending on the final market/use for the biomass.

Collection of residues for energy is most economically viable at clearfell stage; this is because with a clear site, access routes already in place and harvesting teams on site the material can be collected efficiently.

Not all sites are suitable for residue collection, suitability is dependent on many factors including tree species, plantation age, access, soil type and fertility, slope, proximity to watercourses, site size etc.

With good site conditions it is possible to harvest 100-120 green tonnes of brash per hectare, the yield will be reduced by many factors including tree species and soil conditions.

B. FACTORS INFLUENCING SUITABILITY TO COLLECT

<u>Tree Species</u>

The amount of residues, or proportion of crowns and branches on a tree is largely dependent on the tree species. Some species such as Spruce (Picea abies) produce as much as 30-40% residues and 60-70% logwood whereas mature hardwood species tend to produce considerably less residues in the order of 15-20%.

<u>Access</u>

Good site access is important for some collection methods, where the residue is to be chipped on site a large landing area to store and chip the residues is required. Access is not so much a problem for bundling methods as the bundles can be handled in much the same way as logs.

<u>Soil Type</u>

Traditionally in machine clearfelling the residues have been used to construct temporary "roads" through the plantation, the residues are placed under foot of the harvester in a "brash matt" and the forwarders can then travel on the same pathways. Soil type must be suitable to allow reduced volumes of residues under foot without affecting the soil structure. It is also very important that the soil structure is not broken to the extent as to contaminate the residues.

It is vital to maintain good soil structure as damaging it affects trafficability and also creates additional environmental problems by increasing run-off into watercourses.

Soil fertility must also be considered, leaving residues to biodegrade in the forest has been a traditional way to return valuable nutrients and organic matter to the soil, by removing the residues the nutrients and organic matter are also removed from site.

Weather Conditions

Wet weather conditions can seriously hamper any land based activity and this is no different for brash harvesting. Regardless of other factors wet conditions will cause considerable contamination by soil and increased soil damage.

Hard frost weather can be very beneficial as it increases trafficability and reduces soil damage.

Slope

Site slope must be considered when planning to remove residues. In practice higher slopes lead to greater trafficking, in conjunction with the slope the potential for run-off is raised considerably.

Watercourses

Again it is important to limit the potential for runoff from the site. Clearfelling is already known to increase run off, and by the additional activity of removing residues the potential for run-off is raised. For this reason residue collection activities should be curtailed close to watercourses.It is good practice to maintain wide riparian zones around water courses, these riparian zones vary in width depending on runoff risk factors such as slope and soil type.

Site Size

From an economic point of view it may not be practical to bring in residue collection machines to smaller areas or areas distant from normal harvesting operations.

C. Residue Collection Techniques

There are two main collection techniques for residue, both have their advantages and disadvantages; which technique is employed will depend on a variety of factors (including those outlined above). One factor that is common to all collection methods is the logging method. Logging method can be carried out as normal, or the method used can be altered to suit the collection of brash.

1. Logging Methods

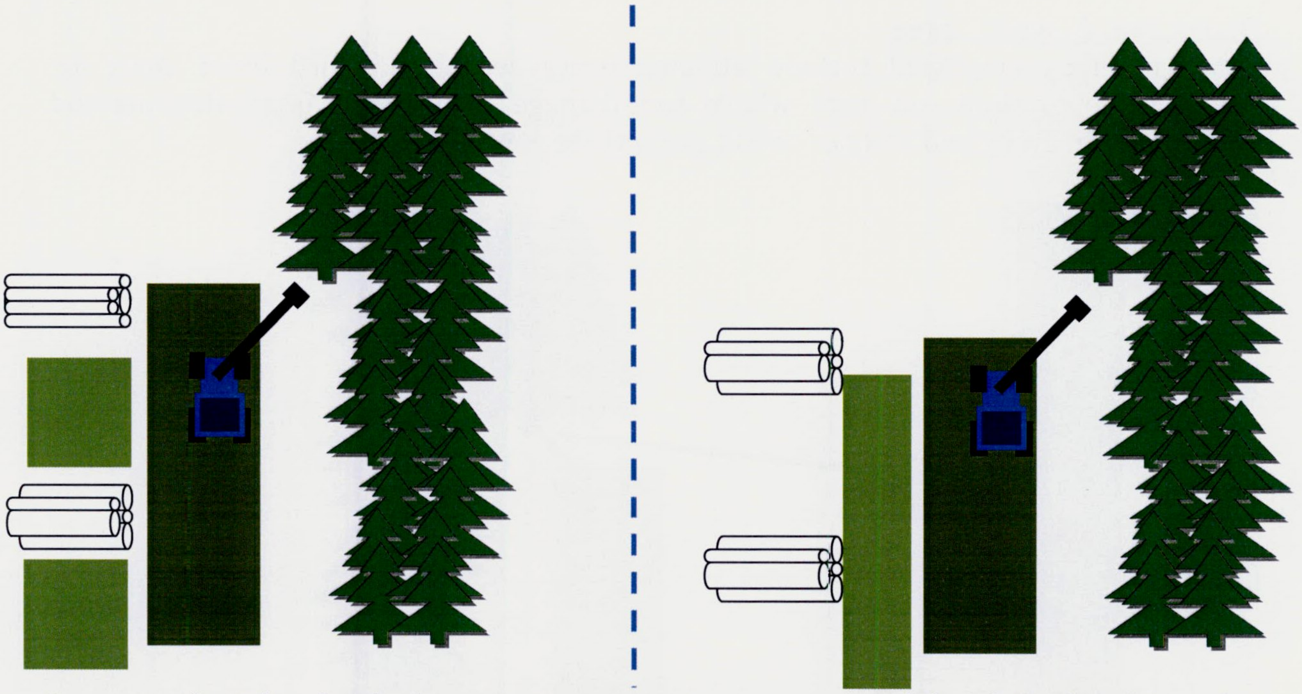
Traditional

The traditional method for mechanical harvesting is for the harvester to work up a line harvesting upto 10 rows deep. The trees are felled and then stripped & crowned in front of the harvester, the side braches and tops fall to the ground in front of the harvester forming the brash matt; the logs are stacked on the opposite side of the harvester to the standing trees. The harvester travels on top of the residues (brash mat) up the length of the plantation.

The forwarder removing the logs then travels on top of the same brash matt collecting the logs and bringing them to roadside.

In order to harvest brash in this operation the brash baler/forwarder can either travel on top of the brash matt or if soil conditions allow it can travel on the bare ground.
This level of traffic (harvester, forwarder & brash machines) can cause considerable contamination from soil where the high levels of traffic infuse the brash matt with soil.

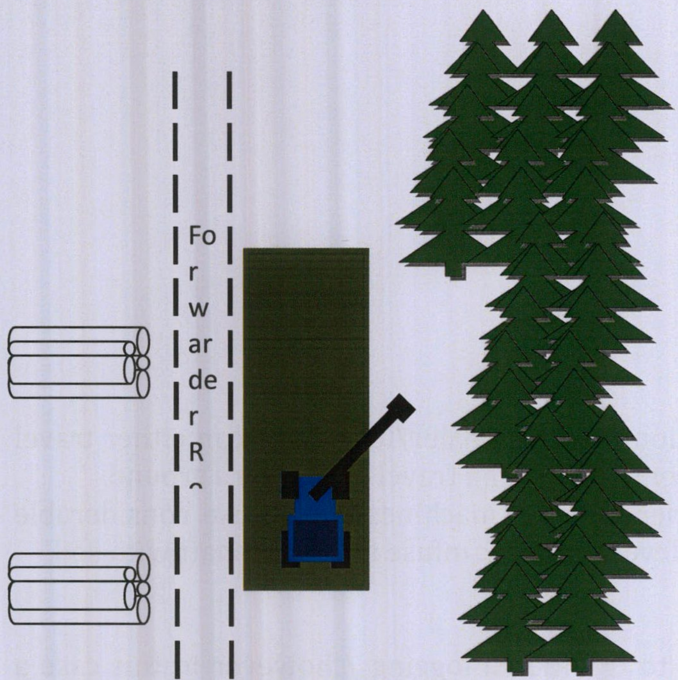
Intermediate Brash Piles / Brash row
These two similar methods are similar to traditional logging / however in this case a portion of the brash is placed into either brash piles in between the log piles or into a brash windrow alongside the harvester route. The brash placed in these piles is not travelled on and is therefore not contaminated.



Care must be taken by the harvester operator to ensure enough brash is placed into the brash matt to prevent soil damage and trafficability difficulties – while at the same time maximising the amount of brash that is "saved" for conversion to biomass

Harvester only brash matt

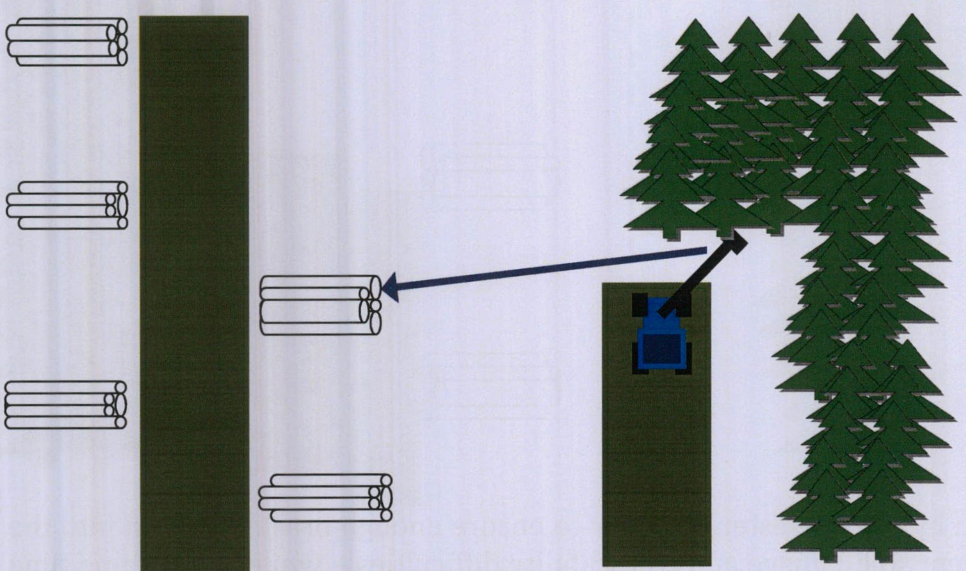
Another method used to preserve the brash is to only allow the harvester to travel on the brash matt. All other machinery travels to the side of the brash matt on the bare soil.



This method does preserve the maximum amount of brash, however it can result in considerable soil damage where the forwarders/brash balers travel.

One in Two / Two in Three

Other methods employed include utilizing every second or third brash matt for forwarder operations, on sites where soil damage may be an issue this method preserves 1 in every two rows or two in every three rows.



In this method the brash rows are spaced to allow the harvester stack the logs from adjoining rows within reach of the forwarder in the next row. This allows the forwarder to travel up one brash matt and collect the logs from adjoining rows without travelling on the brash matt. This method puts a lot of extra work on the harvester and thus may not be favourable.

In many instances it may also be desirable to select sections of tops for stake wood and pallet wood, the harvester operator can obviously place this material to one side in any of the above methods, however it will reduce the quality of material in the brash.

2. Collection Methods

Two methods are utilised for brash collection. Brash baling and direct forwarding.

<u>Brash Baling</u>

A number of brash balers are currently on the market and in operation around the world. Brash balers take in the brash material, compress it and tie twine around the brash. The brash bale comes out in a log type shape cut to a pre-programmed length. In this form the brash bales resemble logs, they can be handled by traditional forwarders and trucks and logistically are easy to transport in this compact form. Balers obviously only bale the material in situ and the bales have to be transported out of the forest at a later stage.

- Brash baling produces a dense form of brash that can be easily handled by existing forestry machines.
- Brash can continue to dry out in the bales.
- Brash logs can be delicate – care must be taken to ensure material is fed in to the baler correctly and that the bales are not of excessive length. One option is to cut the bales at 2.2 meters. Short bales are more robust and can be stacked crossways on road going vehicles.
- A brash baler can be expected to process 1.25-1.75 Ha per day, with up to 120 tones of brash per Ha. Production rates are in the order of 15 to 30 bales per hour depending on site conditions.

Onsite Chipping

Another method is to chip on site. The brash is extracted in its loose form in expanding forwarders/press collectors and transported to the roadside. The brash is then stockpiled to await chipping.

The brash is then chipped directly into trucks / trailers to be transported to the customer or storage facility.

This method requires good access at the roadside to accommodate a stockpile, chipper and trucks. Although in some situations it is possible to have the forwarder on site the same time as the chipper and to reduce the need for stockpile space. It is not possible for a forwarder to keep a chipper going on its own, therefore some stockpile will be required (50%+ pre extracted) on site.

FIGURE 38: Forwarder Collecting brash material

FIGURE 39: Brash material chipped at the roadside

Brash As a Fuel

Brash bales need to be chipped (generally at the site of use) before they can be used, brash chipped at the felling site and brash bales chipped are utilisable in large scale boilers and for Co-Firing, due to its high moisture content and high contamination potential from soil Brash chip is not suitable for all boilers and in particular not suitable for smaller boilers. Brash chip can depending on its moisture content have an energy content of between 2 and 4 MWh/tonne depending on moisture content and degree of degradation.

REFERENCES

Alakangas, E, Sauranen, T. &Vesisenaho, T. 1999.Production Techniques of Logging Residues in Finland.

ETSU & Forestry Contracting Association (2000). "Forest Residue Baling Due Diigence Assessment, Providing & Transport Trials" ETSU B/U1/00589/REP, commissioned by the UK Department of Trade & Industry

Farren C. Spencer Environmental Care Associates, Spencer Ltd. 2011

Forestry Commission (1990).Harvesting Forest Residues – 1989. Work Study Branch Report No 7/90

Forestry Commission, (1996).Integrated Residue Harvesting: Desk Study. TDB Report 8/95.

Hakkila, P.,Nurmi, J. &Kalaja H. 1998. The Finnish Forestry Institute

Lyons J, Coillte Forestry Services.Personal Communication. 2011

Wood Fuels Basic Information Pack – Swedish National Energy Administration. ALTENER II

Worrell K, Worrell Harvesting Ltd. Laois, Ireland. Personal Communication. 2011

VII. THE BIOMASS PRODUCTION IN CASE OF FOREST CALAMITIES

Prepared by: Dr. Corina Berkesy, Dr. Mihaela Begea, Dr.Laszlo Berkesy (ICPE)

A. GENERAL ASPECTS

Some natural phenomena such as storms accompanied by strong winds, massive snow falls and avalanches, as well as torrential rains followed by strong high floods, are the cause of forest damages. These past few years, these phenomena have been characterised by increased frequency and intensity. The forests and their long-lasting management constitute a major priority of the national and international forest policies and strategies. A long-lasting management of the forests calls for accurate information on their condition, updated on a yearly basis and provided on a long term, on a large scale and by intense monitoring.

The negative action of some ***biotic and abiotic factors*** that reduce the capacity of the forest's protection and production functions can be prevented by measure taking, starting with the prevention ones and ending with the fighting ones, if the damaging agent is present, active and is already causing damage.

The ***abiotic*** factors that can cause damages to the forest include : the temperature excesses (scorching heat, frost), draught, torrential rains, snow, winds, floods, fires.

The ***biotic*** factors refer to :

- weeds and vegetal parasites ;
- forest-damaging insects and small animals ;
- large animals that cause damages by pasturing (they stamp down the soil, tear apart or pull out the seedling naturally appeared from seeds).

The temperature excesses, on account of exceeding the normal values for the planets life, as well as the torrential rains, the snow etc. cause damages of their tissues. Frost causes bark and wood breaking, leafage and branches degeneration and eventually their fall. It can frost bite the roots if the soil is not covered with snow (the tree nursery crops and the spruce fir ones). *The late frosts*, that is the spring ones, cause damages to the seedlings having started to form the vegetation, to the trees already leafed out and even bloomed. *The early frosts*, that is the autumn ones, come before the stems are completely lignified and they cause their freezing and the destruction of their tissues.

Heat causes bark burning in case of the trees whose bark is smooth and thin, if directly exposed to sunlight (beech, ash, sycamore maple, fir tree), the ringing of the passing area between the seedlings root and their stem base due to the excessive soil heating, soil drying out, which leads to plants drying. Great heats favour fire break out (Popa I., 2009).

If the rains fall torrentially or last long, they stamp down and/or wash out the nutritional blanket and the humus off the soil, they flood the forest crops, uproot the seedlings and the seedling naturally appeared from seeds, soften the ground and facilitate the wind blow-downs.

B. THE RISK OF THE FELLINGS DUE TO STORMS AND STRONG WINDS

The wind blow-downs represent the main disturbing factor of the mountain ecosystems, with negative effects both from the ecological standpoint, namely by the structural modifications that it induces, and at the economical level, by the wood amount value losses and by the disturbances of the coherent application of the forest management schemes. The passing to a rational, ecology-based silviculture, the conserva-tion, the protection and the long-lasting development of these complex ecosystems nowadays constitute one of the biggest problems of modern silviculture (Fig.ure 40).

The current trends at the international level in the field of risk management, especially of the risk of wind blow-downs, call for a classification of this disturbing factor, as compared to its intensity and amplitude, in two large groups : wind blow-downs with ***catastrophic effects*** and ***endemic blow-downs***.

The peculiarities of each kind of blow-down call for specific methods and techniques of investigation, shaping and prognosis (Popa I., 2009).

Taking into consideration the negative economical and ecological impact of the wind blow-downs, especially of those ***endemic*** in character, with a yearly manifestation, and the necessity of providing solutions of quantitatively assessing the wind blow-downs risk in order to differentiate the silvo-technical measures of increasing the stands stability, the following goals were envisaged :

- defining the concept of wind blow-downs risk and suggesting a typology of the wind-caused damages ;
- analysing the economical impact of the wind blow-downs that have an endemic character, with a view of differentiating the major negative effects on the arrangement schemes application ;
- drawing up and implementing a system of quantifying the decennial risk to the wind blow-downs and the methodology of predicting the probable amount of the wind blow-downs;

The wind blow-downs *with catastrophic effects* are those massive blow-downs due to peculiar weather conditions, that is extremely intense winds, which affect a large area. The delimitation criterion is the amount of calamity-affected wood mass, which reaches hundreds of thousand or millions of m^3, depending on the geographical scale on which the analysis is performed.

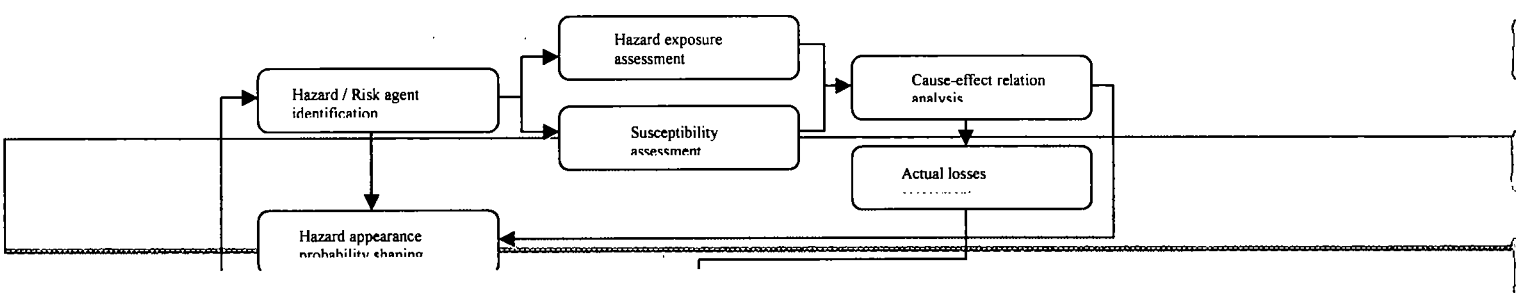


FIGURE 40: Wind blow-downs risk management in case of the forest ecosystems – (a processing of Gardiner and Quine, 2000, taken over by Popa I., 2009).

The endemic blow-downs are those that happen every year in the mountain stands as a result of medium intensity winds, and they have the greatest economical effects by accumulation. Unlike the catastrophic wind blow-downs, this kind of wind disturbance is spatially spread out on large surfaces, affecting most mountain ecosystems with different intensities. They are determined both by the natural and weather factors and by the stands conditions (biometrical and qualitative parameters, structure etc.). Their production is influenced by the silvic measures applied, by the soil and landscape conditions and their intensity can be influenced by appropriate interventions.

This kind of blow-downs cause, at the level of the forest management system, serious disturbances both economically, by the reduction of the wood material quality and by the long-term unbalances on the wood market, and ecologically, by the gradual de-structuring of the stands.

This category of wind blow-downs include, under the generic name of 'endemic blow-downs', both the isolated downfalls or in groups of 5 to 10 trees, and the type of mass downfalls that affect a certain stand or part of it, on the condition that this phenomenon, namely the mass wind blow-downs, is not generalised to a large geographical landmass. (Popa I., 2009).

The risk of incidence of the **wind blow-downs** in Romania's forests are pretty high, according to the existing researches and statistics.

It is thus estimated that out of the total surface of the forest fund (6,025,587 ha), the forests falling into the *very high risk* category cover 12 % (39 forest district facilities) and those included in the *high risk* category 16 % (48 forest district facilities) (Dincă L., 2008). The conclusion is that 28 % (more than a quarter) of the forests belonging to the forest fund run a high and a very high risk of being subjected to wind blow-downs. The forests running a very high risk of experiencing wind blow-downs are almost exclusively concentrated in the Northern part of the Oriental Carpathians (Dincă , L., 2008).

1. *DAMAGES CAUSED BY STORMS WITH STRONG WINDS*

Wind, by the pressure that it exerts upon the soil surface, has got devastating effects on the stands. According to their speed, the more dangerous winds are termed strong winds, storms and hurricanes. The damages caused by the wind vary a lot : downfalls, stem and branch breaks, uprooting.

The kinds of damages (crown and trunk breaks, uprooted and bent over trees) vary, but generally speaking, in the thick stands, uprooting and trunk breaks are dominant, whereas the crown breaks can especially be found in the more rare stands (Figure 41).

In terms of the damages seriousness, it is assessed that, as a general rule, the trees with a damaged crown can still be maintained in the stand, because if the remained crown represents more than six verticils, the up to 50-year old trees re-make their crown 3-5 years later.

Categories of wind blow-downs

- wind blow-downs induced by uprooting ;
- wind blow-downs induced by the trees bending down ;
- wind blow-downs induced by the trees break ;
- dispersed and mass wind blow-downs.

a. b.

FIGURE 41: Wind blow-downs in Colibiţa, Bistriţa-Năsăud county – the Călimani mountains a.- after the storm – 2007; b.- in 2011;

The insect attacks as a result of the wind blow-downs

In their turn, the wind blow-downs favour the mass breeding of the bark beetles and first of all of Ips typographus, which prefers larger-sized and thick-barked trees (which are to be found within the more than 60-year old stands) and which needs a lot of heat for developing itself (it does not find this heat in the closed massive tree ; instead it plentifully enjoys it on the surfaces with thrown down trees). During their mass breeding, these beetles, which usually are secondary pests, can also attack the standing trees and so the converging action of the three factors (the mushrooms that cause the roots and the stem duramen to rot, the wind and the bark beetles) tends to lead to the complete tearing apart of the old stand, instead of providing succession, which could give birth to a new biocoenosis, according to the natural laws.

The natural succession or the way that this one indicates is not however accepted by man. Always in a hurry, as usual, he does not want to see that all the advantages forecast upon the crop installation are blown off. Because of the wind blow-downs, which impose the stands exploitation to be made long before the completion of the production cycle foreseen, by the standing drying out of countless trees due to the beetle attacks that happen shortly after the downfalls, and also seeing the fact that a large portion of the exploited wood is dote, the damages noticed exceed by far all the advantages obtained by the management manner applied (Olenici, N.,1996).

2. *DAMAGES CAUSED BY THE SNOW FALLS*

Wet snow is harmful to the forest by the fact that it adheres to the branches and burdens the trees tops, causing them to bend over and eventually to break. There thus appear blanks in the stand, which are highly prejudicial to the stands stability (they reduce growth, wood depreciates itself, they favour insect attacks). This is the case of the resinous trees – the pine, the spruce fir, the fir tree – and of some deciduous trees : the locust, the beech, the poplar, the alder (Fig.ure 42)

The resinous tree stands, especially the pine, spruce fir, fir tree, douglas ones, and under certain circumstances the larch and even the deciduous trees are more affected by the snow.

The kind of damages (crown and trunk breaks, uprooted and bent over trees) vary, but generally speaking, in the **thick stands**, the uprootings and the trunk breaks are dominant, whereas in the **more rare stands**, the crown breaks are more frequent.

FIGURE 42: Damages caused by the avalanche in Bistrița-Năsăud county – the Călimani Mountains

3. *DAMAGES CAUSED BY FLOODS*

The absence of water or its presence in excess has got negative effects on the forest. Water deficit thus brings forth leaf fading, growth cessation, trees drying out and the death of the seedlings and of the seedling naturally appeared from seeds. The excess of water (the floods) leads to the root asphyxiation and eventually to the trees vitality drop or even death (Figure 43).

- The levels and flow rates increases happen in spring, due to snow melting and to the rains and in summer due to the abundant rains, on small surfaces.
- The high floods happen for short period of time, but they carry large amounts of alluvial deposits (such as blocks, gravel, floating objects).

- The waterbeds are narrow, high-sloped and composed by blocks and grav.
- Due to the land configuration, within the affluents on the right side, with Southern exposure, the high spring waters grow faster than the left affluents, which are North-exposed and where snow melting happens later on.

FIGURE 43: ig.4. Floods in Bistrița-Năsăud county – the Rodna Mountains - Valea Secii - 22.07.2010

4. *PREVENTING MEASURES*

Measures for avoiding the risks in case of wind blow-downs

Drawing up and implementing risk management systems in case of wind blow-downs must be a key component of the strategies for the long-lasting development of the mountain forest ecosystems.

Taking into account the negative economical and ecological impact of the wind blow-downs, notably of those endemic in character, with yearly manifestation, and also the need of providing risk quantitative quantification in case of wind blow-downs, in order to differentiate the silvo-technical measures of enhancing the stands stability, the following goals were aimed at :

- defining the concept of risk in case of wind blow-downs and suggesting a typology of the wind-caused damages ;
- analysing the economical impact of the wind blow-downs with an endemic character, with a view of highlighting the major negative effects on the arrangement schemes application;
- drawing up and implementing a system of quantifying the decennial risk to the wind blow-downs and the methodology of predicting the probable amount of the wind blow-downs (Popa I., 2009).

By applying the probabilistic template of quantifying the wind blow-downs risk in case of the stands from the Rotunda production facility I and Cârlibaba Forest District Facility, for the 1999-2008 decade of arrangement application, a total amount of 99310 m^3 of accidental products and approximately 10000 m^3 thereof on a yearly basis, respectively, was forecast.

The total forecast amount of accidental products is a realistic one, taking into consideration the modifications of the structure on age classes and the amount of accidental products had these past three decades.

In case of the Rotunda production facility I, the forecast is an increase in the amount of accidental products originated from wind blow-downs as a result of the enhancement of the weight of the more than 83-year old stands as compared to the previous decade.

This probabilistic template renders a quantification of the general susceptibility of the stands belonging to a production facility to the wind risk factor. It offers the possibility of adapting the medium-term, i.e. decennial forest management strategies and schemes.

For each risk area one will apply the specific silvo-technical measures for enhancing the strength to the wind blow-downs stipulated in the ruling documents for selecting the afforestation schemes and composition, the application of the stands care and management, the treatments application.

The majority of these classification systems analysed are adapted to the endemic downfalls, considering, for the catastrophic downfalls forecast, the necessity of using specific modelling and simulation techniques in the field of the extreme values analysis. (Popa I., 2009).

The damages prevention and mitigation measures (Barbu,I., 1982; Barbu, I., and Cenuşă, R., 1987) consists in :

- classifying the high risk areas upon the appearance of the massive snow falls and avoiding the installation of vulnerable (resinous) forests in these areas. Obviously, in the high risk areas the resinous forests are missing or they are rare and mingled up.
- in the high risk areas where resinous crops have been set up, more detailed classifications will be made, in the sense of establishing the intervention emergencies for stabilising and enhancing snow resistance.

The classification will mainly aim at : determining the altitude band with a high risk of appearing snow-caused damages (Barbu, I., 1979 ; 1982) ; delimiting the landforms subject to the probable intensity of the snow-caused damages (Barbu, I.,1982) ; delimiting the resinous crops on age classes, thickness categories, composition.

5. *ACCIDENTAL PRODUCTS (WIND- AND SNOW-CAUSED BLOW-DOWNS) EXPLOITATION WORKS*

The works below are performed in case of the wind blow-downs :

- barking off all the wind-thrown down trees, both those in the downfalls perimeters and the isolated ones ;
- throwing down and barking off the wind-bent over trees and the ones remained isolated in the downfalls area, of the ones injured by the fall of other trees, of those attacked by the insects ;
- the trees barking off has to be made all the way to the top, including the remainders and the stumps remained unbarked ; the barking off should not be made by stripe pulling out.

In terms of technically organising and capitalising the wood derived from the wind downfalls, the procedure is the following one :

In both situations, that is both in case of the dispersed wind blow-downs and of the mass ones, one proceeds to the arrangement of the access ways for the machines and for the carts, on the approval of the silvic organisms and on the observance of the effective instructions :

- ❖ endowing the labour team with the necessary carts and machines ;
- ❖ providing lodging for the workers coming from other places and their transportation from the worksite to their domicile twice a month ;
- ❖ providing the means for the wood transportation ;
- ❖ performing the technological processes a.s.o.

The detailed technological process, more frequently used in Romania's mountain area, for exploiting the wind blow-downs, can be rendered in the following way :

The trees throwing down in case of the ones put down by the wind and by the snow only refers to the trees broken from certain heights of the stem, partially to those bent over and only to the trees that are marked up and indicated to be marked up. In case of the uprooted trees, one only makes a sectioning at the stump, for the detachment therefrom. In this case, one performs such additional operations as :

- removing (cleaning) the earth that has covered the trunk of the uprooted trees (in the sectioning area),
- anchoring the trees by means of a cable or providing their stability by means of stakes.

Exploitation phases and work systems

As for the forest exploitation operations, it is possible to make the difference among the following exploitation phases :

- throwing down : throwing down a tree from its stump in such a way that the tree falls on the ground ;
- processing : branch cleaning (namely removing the branches from the trunk and pollarding) and cutting (cutting the trunk at preset lengths) ;
- carrying by using ropes : wood transporting from the throwing down place to the extraction ways ;
- haulage : wood transporting along the extraction ways till the unloading place ;
- barking off : partially or completely removing the bark from a stump ;
- transportation : wood carriage on the forest and public roads ;
- transformation : wood reduction for its utilisation as fuel (cutting, splitting, chipping).

The importance of the chipping operation has increased these past few years, which is due to the fact that chipping makes possible the exploitation and the maximum capitalisation of the wood biomass, otherwise unused.

There are two main work systems within the forest exploitation operations :

- the reduced exploitation system – RES : processing is made at the throwing down place in the forest and the stumps meant to marketing are hauled ;
- the complete exploitation system – CES : after being thrown down, the whole tree is hauled and processing is made either on the forest road or at the unloading place.

Out of the abiotic factors, the highest risk for the destabilisation of the forest ecosystems was run by the wind and snow blow-downs and breaks.

The most numerous stands affected by wind and snow blow-downs and breaks (80-85%) were traced in the Oriental Carpathians and the least numerous in the Curved

Carpathians (4%), the Meridional Carpathians (3%), the Apuseni Mountains (6%), Banat (1%) or the Romanian Plain (4%) (Figure 44)

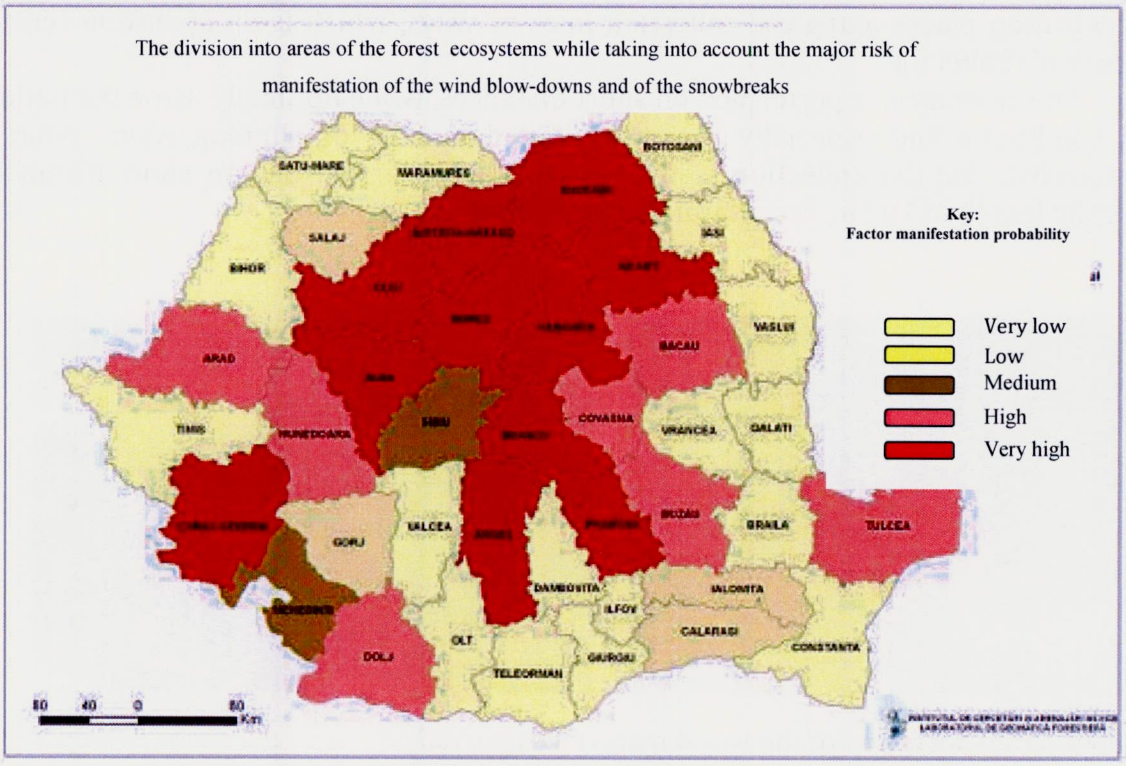


Figure 44: The division into areas of the forest ecosystems while taking into account the major risk of manifestation of the wind blow-downs and of the snowbreaks (http://www.madr.ro/pages/cercetare/ps_812_faza_5.pdf)

In the area of the forest district facilities of Gheorghieni, Sânmartin, Borsec, Tulgheş and Topliţa from Harghita county, as well as Comandău, Covasna, Sânzieni of Covasna county, the pastures mainly afforested with spruce firs, with ages exceeding 60 years, were severely affected by this calamity. The exploitation and the capitalisation of the put down or broken wood material on these pastures were made with difficulty, which thus created optimum conditions for the infestation of the standing trees and the formation of hotbeds of standing trees attacked by stem insects and subsequently inclined to dry out. The liquidation of such hotbeds was made very late and the negative consequences upon the forest were felt many years afterwards, which led to the appearance, in the following years, of the attacked standing trees. (http://www.madr.ro/pages/cercetare/ps 812 faza 5.pdf)

6. *THE TECHNOLOGY OF EXTRACTING THE WOOD MASS FROM THE CALAMITY-AFFECTED AREA*

By the process of wood collection, the wood biomass is carried from the tree throwing down place to the primary platform or in the shaping-loading places arranged at the junction with the long-distance transport ways.

Subject to the dimensional elements of the biomass and to the transport capacity of the collection means, it is necessary for this one to be carried on the shortest way, with reduced expenses and consumptions, from the throwing down place to the concentration places along the collection lines or ways, which is an operation termed 'collection' (Tabel 5).

This operation is performed on short distances, while optimally using the natural land conditions and especially the gravitational moving or slipping ways. What is characteristic for the collection is the fact that it is carried out on short distances, generally less than 100 m, on natural dispersed routes.

Figure 45: Transportation of the wood material extracted

The shifting from these points where the wood is collected to a permanent transporting equipment, by using a certain route and a certain means of collection, is termed 'wood approaching'. In certain situations, the concentration points or the places where wood is collected by other means are not in the action range of the collection means, so a new movement to the latter ones is needed, which is an operation termed 'wood taking out'.

In certain land and stand conditions, the taking out and approaching operations are performed continuously, by using the same means, the collection process being also termed 'taking out-approaching operation.

Technological process (phase)	Activities or operations :
1	2
1. Wood harvesting	1.1. Trees throwing down 1.2. Removing the branches off the trees or off the tree parts 1.3. Wood barking, if necessary, according to the instructions no. 572/91 1.4. Sectioning the round wood
2. Wood collection	2.1. Rounding off the thick end of the trunk 2.2. Wood pre-sorting at the stump 2.3. Taking the wood from the stump to the haulage place, when needs arises 2.4. Collecting the wood by using cattle and creating loads along the tractor road 2.5. Hauling the round wood and creating concentration points for the final taking up operation 2.6. Binding the wood from the concentration point onto the tractor 2.7. Taking up the wood by means of the winch and creating loads for the tractor 2.8. Approaching the wood to the primary warehouse
3. Wood processing in the final warehouse	3.1. Untying the load from the tractor 3.2. Preparing the wood for being loaded 3.3. Wood piling up 3.4. Wood loading in the means of transport 3.5. Wood reception and dispatch
4. Felling area cleaning	4.1. Collecting the exploitation remainders and forming lines as per the effective norms 4.2. Creating the fire prevention strip perimetrally to the felling area surface

TABLE 5: The wood material extraction technology (Palmaru, V., 1995)

Rendering the forest fund accessible constitutes the first step in introducing and expanding wood exploitation mechanisation, on the one hand for taking the mechanical work machines to the wood harvesting place, and on the other hand for collecting and introducing in the economical circuit the wood mass highlighted and foreseen in the arrangement possibility (Figure 45.).

C. BISTRIȚA-NĂSĂUD COUNTY – ACCIDENTAL PRODUCTS

Bistrița-Năsăud county has a 5355 km^2 landmass, out of which the forests cover 35.7%; they are an extremely important resource for the future development. The vastest surfaces of forests are in the Rodna (30.9 %), Năsăud (24.9 %) and Bîrgău (15.1 %) sub-areas and they represent more than 2/3 of the forest fund.

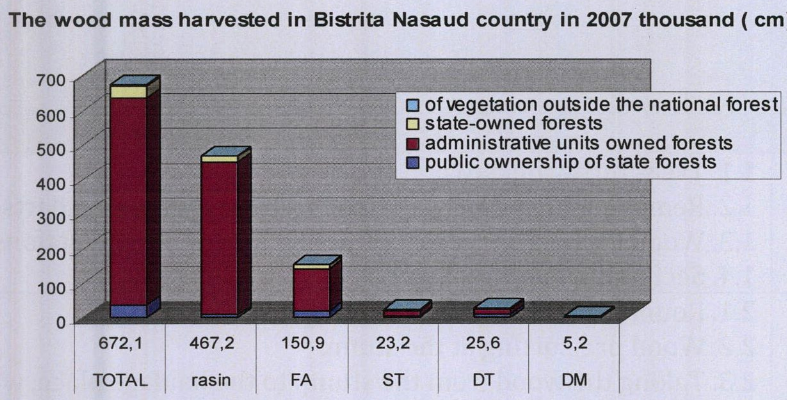


Table 6: The wood mass harvested in Bistriţa-Năsăud country during 2007

The figure above shows the amount of wood material harvested in Bistriţa-Năsăud county in 2007, according to the harvested species (Table 6)

The tables below present the harvests of main materials and accidental products - wind-fallen trees, on age categories (ACCI, ACCII), avalanche-caused downfalls), as well as trees fallen down or damaged by high floods (Table no.2-6).

The tables also underline the amounts of wood material harvested from the forests that are the State's public property (Table no.2), from the forests that are the administrative-territorial facilities' public property (Table no.3), from the private property forests (Table no.4).

The wood mass harvested by acknowledged legal entities - 2007

Table no. 2

No.	From the forests that are the State's public property	MU	Qty
1	Main products	thousand cm	22.2
2	Accidental products from the more than 60-year old surface of land with trees and bushes (ACCI)	thousand cm	3.3
3	Accidental products from the less than 60-year old surface of land with trees and bushes (ACCII)	thousand cm	0.4
	Total	**thousand cm**	**36.8**

Table no.3

No.	From the forests that are the administrative-territorial facilities' public property	MU	Qty
1	Main products	thousand cm	99.2
2	Accidental products from the more than 60-year old surface of land with trees and bushes (ACCI)	thousand cm	299.8
3	Accidental products from the less than 60-year old surface of land with trees and bushes (ACCII)	thousand cm	61.8
	Total	**thousand cm**	**565.1**

Table no.4

No.	From the private property forests	MU	Qty
1	Main products	thousand cm	6.7
2	Accidental products from the more than 60-year old surface	thousand cm	7.9

	of land with trees and bushes (ACCI)		
3	Accidental products from the less than 60-year old surface of land with trees and bushes (ACCII)	thousand cm	3.6
	Total	**thousand cm**	**23.1**

The wood mass harvested by natural entities - 2007

Table no.5

No.	From the forests that are the administrative-territorial facilities' public property	MU	Qty
1	Main products	thousand cm	2.7
2	Accidental products from the more than 60-year old surface of land with trees and bushes (ACCI)	thousand cm	15.8
3	Accidental products from the less than 60-year old surface of land with trees and bushes (ACCII)	thousand cm	2.0
	Total	**thousand cm**	**31.3**

Table no.6

No.	From the private property forests	MU	Qty
1	Main products	thousand cm	0.9
2	Accidental products from the more than 60-year old surface of land with trees and bushes (ACCI)	thousand cm	2.6
3	Accidental products from the less than 60-year old surface of land with trees and bushes (ACCII)	thousand cm	1.2
	Total	**thousand cm**	**11.4**

TABLE 7: The tables present the amounts of wood mass, of main products and of accidental products harvested in Bistriţa-Năsăud county in 2007 (Tabel no.7).

Forest district facility (FDF)	Surface	Amount	Exploited amount	Remained to be exploited
F.D.F. Bistriţa	802.3	12695	8538	4157
F.D.F. Izvorul Someşului	7817.81	59360	48021	11339
F.D.F. Maieru	2078.5	11333	10853	480
F.D.F. Bistriţa-Bârgăului	1705	27867	21683	4640
F.D.F. Valea Ilvei	2919.3	18745	15944	2801
F.D.F. Cormaia Anieş	398.5	2625	2521	104
F.D.F. Romuli	3487.4	137660	72126	65534
F.D.F. Telciu	5471.394	164723	98634	66089
F.D.F. Josenii Bârgăului	1498.1	68921	44237	19684
F.D.F. Someş Ţibleş	2255.3	96020	74033	21987

F.D.F. Dealu Negru	2066	25954	16749	9205
F.D.F. Plaiurile Heniului	779.8	8782	8042	740
F.D.F. Bistriţa chief town	2340.6	6067	4326	1741
F.D.F. Tihuţa Colibiţa	4396.5	113065	90012	23053

TABLE 8: The breakdown of the wind blow-downs in Bistriţa-Năsăud county on 23.03.2007

Table no.8 lists the amounts of wood material affected by the 23.03.2007 wind blow-downs, the corresponding surfaces, as well as the amount exploited and the one that remained to be exploited. The amounts remained to be exploited are mainly due to the difficultly accessible areas where the storm took place.

On the territory of Bistriţa-Năsăud county there are two national parks fallen into U.I.C.N.'s 2^{nd} category :

- Rodna Mountains National Park, with a 46,399 ha surface, out of which 37,429 ha in Bistriţa-Năsăud county ;
- Călimani National Park, with a 24,041 ha surface, out of which 112 ha in Bistriţa-Năsăud county.

The park's surface is 46,399 ha, out of which 36,974.0 ha (80 %) in BN county and 9425.0 ha (20 %) in Maramureş county ; 44,000 ha are declared reservation of the biosphere. The total surface affected and the total amounts affected on a yearly basis were taken into account.

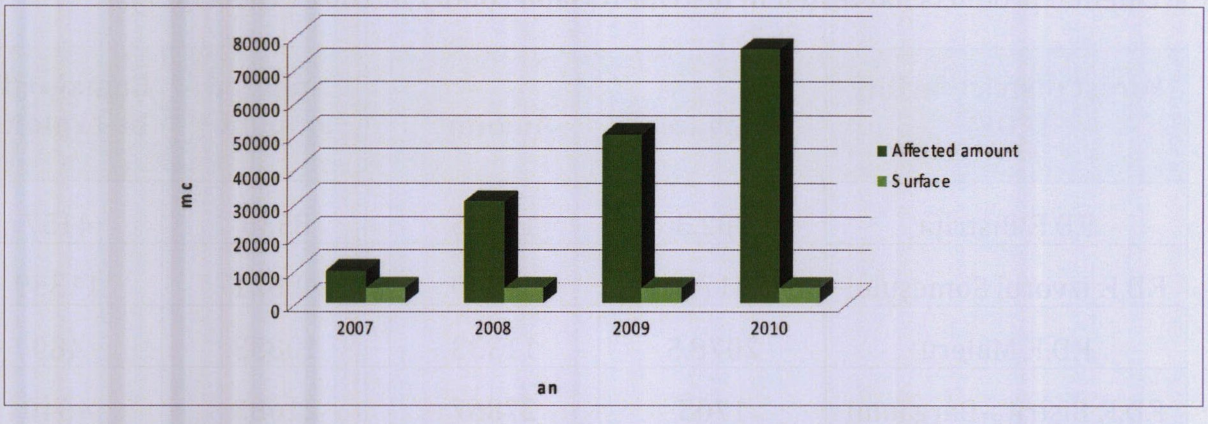


TABLE 9: The breakdown of the accidental products in the Rodna Mountains National Park between 2007 and 2010

The measures taken in case of the accidental forest products resulted from the wind blow-downs happened on the territory of the Forest District Facility Josenii Bârgăului – Production Unit I – Colibiţa and Production Unit II –Dornişoara, as a result of the 23.03.2007 storm, are presented below. The surface affected by the storm was of 2150.2 ha in the former case and of 1827.6 ha in the latter one.

Table 10 Wind blow-downs at the Production Unit II – Dornişoara, Bistriţa-Năsăud county

Because of the landforms in that place and also because of the factors linked to the structure, the age, the density and so forth of the surface covered with trees and bushes, the downfalls happened in all directions. A jumble, hiping up and mess, so to speak, situation emerged. In some places, the trees fallen down ones on the others formed real 'bridges'.

It goes without saying that the exploitation of the dispersed wind blow-downs imposed on a certain way of organisation and exploitation and the exploitation of the mass ones brought forth other technological processes, greater physical efforts, greater pecuniary and labour security efforts, specific infestations prevention measures etc.

The affected wood material amount was 9,1311 cm in Colibiţa (Fig. 2.) and 213763 cm in Dornişoara (Table 10), which is the amount of wood mass that was harvested between 2007 and 2009. In this case, as many as 60874 trees and 164433 trees, respectively, were extracted from that area (Fig.ure 46).

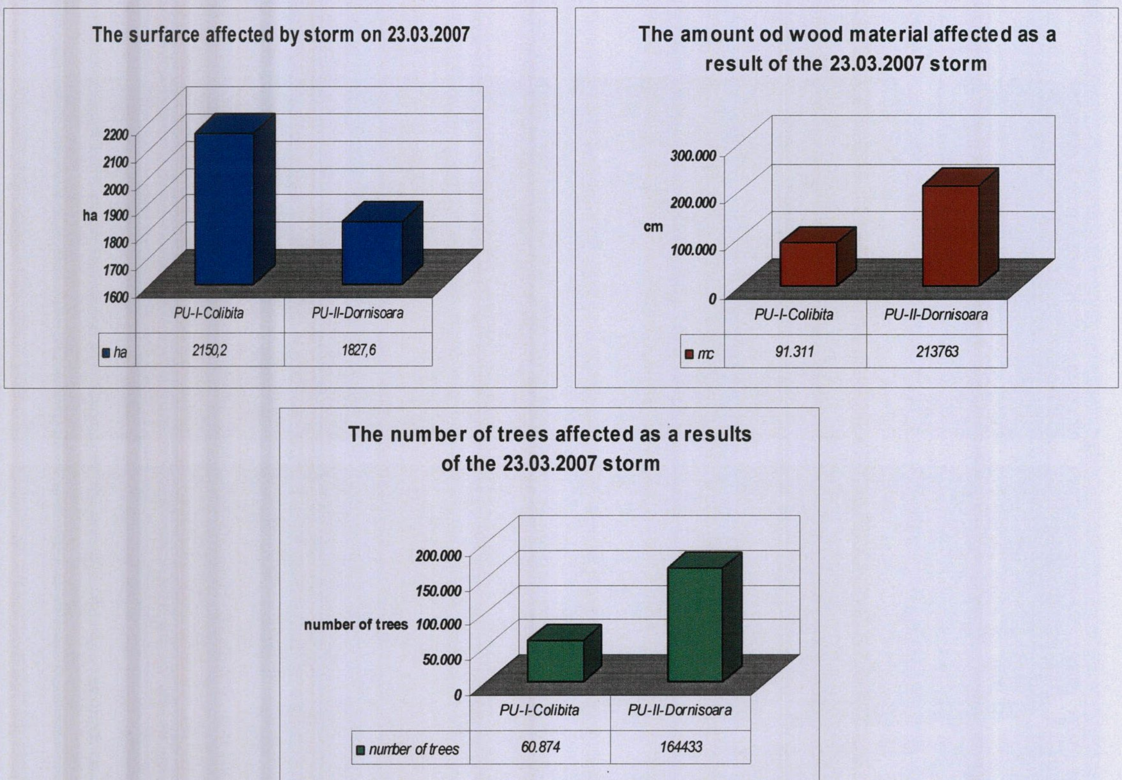


FIGURE 46: The 23.03.2007 wind blow-downs in the Forest District Facility Josenii Bârgăului, Bistrița-Năsăud county

Methods of taking out, collecting and transporting the wood material from the forest : the works of assessing the amount of wood meant to marketing purposes were completed by the creation of parts tendered and exploited by licensed undertakings.

The time when the wood material was taken out of the forest : the capitalisation was made between 2007 and 2008 and the exploitation was performed between 2007 and 2009.

The quality of the extracted wood material: the vast majority of the affected wood mass had a good quality (uprooted trees and trees bent over by the wind).

Insect attacks prevention measures : first of all the dispersed wood mass and then the mass one were dealt with and Cluj-type pheromone traps and trap-trees were also set up.

The period of time estimated for remedying the affected area : after the wood material was taken out and the constituted parts were received again, the surfaces affected by the wind were planted with the species corresponding to the natural type of forest and after the completion of the massive condition characterised by the approaching of the trees crowns, ecosystemic relations of interdependence amongst the trees and thus a forest-specific environment were created on the inside.

The manner of using the wood mass resulted from the wind blow-downs

The following were exploited and released to production :

- wind blow-downs caused by uprooting ;
- wind blow-downs caused by the trees bending over ;
- wind blow-downs caused by tree break ;
- dispersed and mass wind blow-downs.

- ***The wood mass resulted from the wind blow-downs was tendered by wood mass processing companies.***
- ***The wood remainders were subsequently sold for domestic utilisations, i.e. as firewood for heating purposes.***

Conclusions

The finding is that the trees that have certain flaws on some parts (that is deer gnawing, haulage-caused scratching etc.) and those whose litheness coefficient is a lot over-unitary (1.15, 1.25 and even 1.35) are the first to be broken by the wind or by the snow at various heights (Popa, I.,2009).

The descending direction is very different. The finding was that on the same surface there were trees fallen down top upstream, some others top downstream and in case of the trees fallen on the contour lines, the falling directions were opposed and many more others.

From the exploitation standpoint, the wind blow-downs require more demanding exploitation technologies.

For continuing to prevent the wind and snow breaks and blow-downs, special importance is deemed to be paid to care taking and also to the cleaning and thinning out works, which have to be performed as soon as possible, at a higher intensity as possible and within allowed ecological limits.

Great attention also has to be paid to the performance of such works on the margins and skirts of the young stands, with a view of mitigating the effect of the aforesaid calamities.

D. REFERENCES

1. BARBU, I., 1982: Zonarea pe baze geomorfologice a vulnerabilităţii la zăpadă a arboretelor. Buletinul societăţii de geografie din R. S. România, serie nouă. Vol. VI (LXXVI) Bucureşti.

2. BARBU, I. şi CENUŞĂ, R., 1987. Asigurarea protecţiei arboretelor de molid împotriva doborâturilor de vânt şi rupturilor de zăpadă. Seria a II-a ICAS, Bucuresti.

3. BARBU,I.,. 2004, Metode de evaluare a riscului de apariţie a vătămărilor de zăpadă în pădurile din România , Bucovina Forestieră XII, 1- 2,

4. DINCĂ, L., 2008: Definirea, evaluarea şi zonarea riscurilor pentru pădurile României – CLIDOIN" - Contract CEEX 736/2006-2008, raport ştiinţific, arhiva ICAS

5.OLENICI, N., 1996: Protecţia pădurilor de molid împotriva factorilor biotici şi abiotici dăunători în contextul gospodăririi durabile a acestor păduri. În: Molidul în contextul silviculturii durabile. Simpozion dedicat Dr. ing. Radu Ichim, fondatorul Stațiunii Experimentale de Cultura Molidului, la aniversarea vârstei de 75 ani. I.C.A.S.- S.E.C.M.

5. PALAMARU, V., 1995: Importanța utilizarii în exploatarea doborâturilor de vânt şi zăpadă a unui proces tehnologic cât mai adecvat cerințelor silvice, anul III, nr. 2.

7. POPA, I.,2009: Doborâturi produse de vânt - Factor de risc în ecosistemele forestiere montane, Analele ICAS, 48.

8. Evaluarea şi monitorizarea modificărilor globale de mediu asupra ecosistemelor forestiere; refacerea/ conservarea biodiversității pentru reconstrucția forestieră ecologică ,Contract nr. 373/2006, referat stiintific de etapa

9. http://www.madr.ro/pages/cercetare/ps 812 faza 5.pdf.

10. Additional sources - ITRSV Bistrița and Ocolul Silvic Josenii Bârgăului, Bistrița Năsăud

VIII. WOOD BIOMASS PRODUCTION IN MOUNTAINOUS REGIONS

Prepared by: Bernd Poinsitt (WVB-Stmk GmbH)

The combination of modern cable logging techniques and a well-developed network of forest roads provides the basis for efficient timber extraction and transportation in mountainous regions. Importantly, the approach protects and conserves the natural ecosystem. Transport damage to soil and trees can be minimised by efficient planning, organisation and work procedures. In recent years, the extent and importance of cable logging have increased steadily, and technical developments have been refined with economic and ecological considerations in mind. The Austrian Federal Forestry Office and a number of Austrian forestry operations have also made decisive contributions to that trend. Austria represents a classic cable logging country since more than 60% of its total forest area is inaccessible to vehicles and timber can be harvested only with cable logging devices. As a result, improving access to felling sites is particularly important since this will reduce timber extraction and transport distances and enable an optimal degree of mechanisation, thereby reducing the overall work load and enhancing worker safety.

A. VALUE CREATION CHAIN OF FOREST WOOD CHIPS

In previous years, wood chips obtained through forestry operations have remained a minor element among fuel sources since supply costs were too high compared to sawmill by-products and tree bark. Accordingly, less expensive alternatives were utilised. However, given the growing demand for wood-based fuels, considerations about the availability and supply of raw materials as well as their associated costs and attendant logistics have increasingly become a prime concern. The availability and geographical distribution of wood as a resource for energy generation has become significantly more important both in terms of political decision-making and commercial interests.

In general, wood is a scarce commodity which is dispersed thinly over large areas. It also has a low intrinsic value in terms of price per unit volume or weight. Further, wood is a bulky fuel, which makes it transport intensive. This is particularly problematic in the supply chain for "wood chips", as costs increase as a result of the low load density of the wood (especially in the case of logging residue). Transportation, therefore, is a key element of consideration. Essentially, the optimisation of energy wood production is a function of minimising transport costs. By extension, decisions about when and where logging residues or energy wood will be processed into wood chips and how the material will be transported become essential factors in the supply chain.
The increasing demand for forest wood chips sometimes causes capacity bottlenecks that jeopardise the continuous supply of fuel to heating plants.

When cable logging is used in whole-tree harvesting operations, the resultant chipping residues offer a viable means by which to obtain energy wood as a by-product of the wood production process. Here, the most significant cost advantage derives from the fact that the chipping residue to be processed accumulates directly on the forest roads.

Thus, the chipping process is optimised by pre-concentration of the chipping residue. Different capacity utilisation potentials occur where chipping and transport intersect based on the decision to accomplish the chipping directly in the transport vehicle or on the surface of the forest road. If the chipping residue is stored for a period of time, the drying that occurs not only can increase the quality of the wood chips, but may also lead to a substantially more effective utilisation of the available transport capacity.

A forest wood chip supply system consists of a series of varied processing, transport and control processes intended to convert wood-based biomass into fuel, a resource that is then transported from forest to consumer. Understandably, wood chip supply systems are centred on the chipping process and the wood chipping machine's position within the overall value creation chain determines the condition of the biomass during the transport process. Possible chipping locations include the wood harvesting site, the surface of forest roads, the storage location or the plant at which the wood is used to generate energy. The biomass can be transported as logging residue, energy wood, compressed bundles or wood chips.
In various studies, the chipped wood material is categorised into logging residue and energy wood.

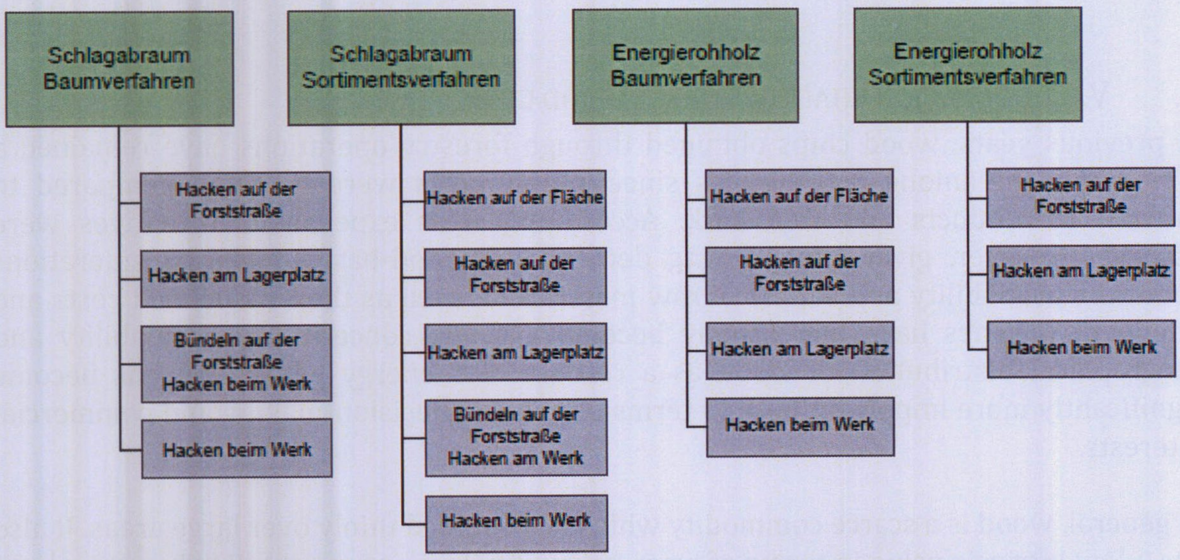


FIGURE 47: Wood chip supply systems classified by raw material and chipping site

Logging residue, i.e. the co-products of conventional tree harvesting, such as branches, treetops and offcuts, offers the advantage that the costs associated with tree felling and extraction/transport of the material are already included in the cost of raw timber production. Relative to the quantity of round timber harvested, however, significant variations are apparent in the amount of logging residue. For example, where deciduous trees are concerned, the quantity of energy wood ranges from 6% to 26% of the total amount of round timber harvested. Conversely, among conifers, that quantity ranges between 10% and 15%. In addition, the extraction of logging residue may carry ecological risks and cause girth increment losses since the trees are deprived of important nutrients.

Energy wood, in contrast to logging residue, is used exclusively for heat generation. First-time thinning of coniferous and deciduous forest areas as well as silvicultural measures in coppiced woodlands fall into this category. Since these operations generally yield small-sized trees, it is difficult to process them efficiently into wood chips; however, that remains an important requirement in the context of forest maintenance and conservation measures. This category also includes felled trees, the tops and branches of which have been lopped off for use as fuel.

Loading density and transport distance are determining factors in the successful production of energy wood. Chipping at the felling site is seldom utilised in mountainous areas. Under such conditions, the most common approach is that of chipping the wood on the forest road, then transporting the wood chips to the intended destination. This closed chain of operations often leads to machine-based shortfalls, such as when a wood chipper is required to wait for a transport vehicle or vice-versa. From the logistical standpoint, the challenge is to organise the entire process such that the waiting times inherent in the sequence of operations are minimised.

Another problem associated with operations in mountainous conditions is that of space constraints on forest roads. The wood chipper must be positioned beside the transport vehicle to enable direct loading, which requires a given amount of space. A possible solution is separating the chipping and transportation processes (interrupting the chain of operations), thus leading to machine independence. In that case, however, additional costs are associated with the loading process. Another approach may be to concentrate the chipped material in advance at central storage locations.
Especially in mountainous areas and small-scale forestry operations, it is worthwhile to establish central storage locations near the forest where harvesting takes place. The primary functions at such storage facilities include bundling certain wood quantities, drying chipped material and ensuring that heat generation plants receive a steady supply of wood chips. Economies of scale have a positive effect on the productivity of the wood chipper and ensure that it will be used to full capacity. As noted previously, drying improves the quality of the wood chips and ensures that the load capacity of the transport vehicle is utilised more efficiently.
Storage facilities located near public roadways also make it possible to use standard modes of transport for wood chips, such as tractor-trailers with containers. The buffer function of storage areas located in mountainous regions is of particular importance during the snowy winter months. Indeed, the setup costs of such storage facilities may be outweighed by the positive effects they provide.
Chipping at the plant causes the transport and chipping processes to remain independent of each other. Under these conditions, the biomass is transported to the plant in the form of logging residue, whole trees or shortwood. One basic disadvantage of this system is that transport vehicle loading capacity cannot be used to optimum efficiency. Nevertheless, the use of stationary, heavy-duty wood chippers makes it possible to chip a wide variety of biomass while simultaneously ensuring high levels of productivity. That advantage becomes even more important when greater volumes of raw materials are used, but such machinery requires high investment costs.

B. VARIOUS SUPPLY SYSTEMS

1. *LOGGING RESIDUE FROM CABLE LOGGING USING THE WHOLE-TREE HARVESTING SYSTEM – CHIPPING ON THE FOREST ROAD*

In general, trees are felled at forest sites using power saws. In the whole-tree harvesting system, the subsequent extraction, transport and processing cycles are accomplished by a single piece of equipment: the processor. The logging residue (branches, treetops and other wood) is stored temporarily alongside the forest road. After a drying phase, the logging residue is chipped and loaded by a heavy-duty wood chipper directly into a container truck waiting on the forest road (Figure 48). This increases transport load density since the wood is chipped and therefore less bulky than typical logging residue. Transportation to the plant is accomplished by container trucks that utilise modular containers (Figure 49). This method is the most commonly used approach to processing logging residue associated with whole-tree harvesting.

By chipping and loading directly into the container, no further steps are required for loading, thereby avoiding additional handling costs. The necessary coordination between the wood chipper output and the transport capacity of the container truck requires significant organisational effort. Depending on the sequence of operations followed, the wood chipper may be required to wait for a transport vehicle or vice-versa (closed chain of operations).

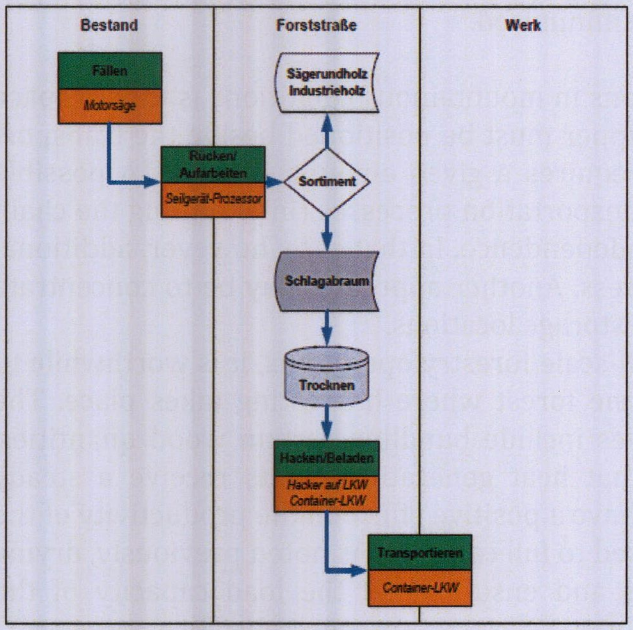
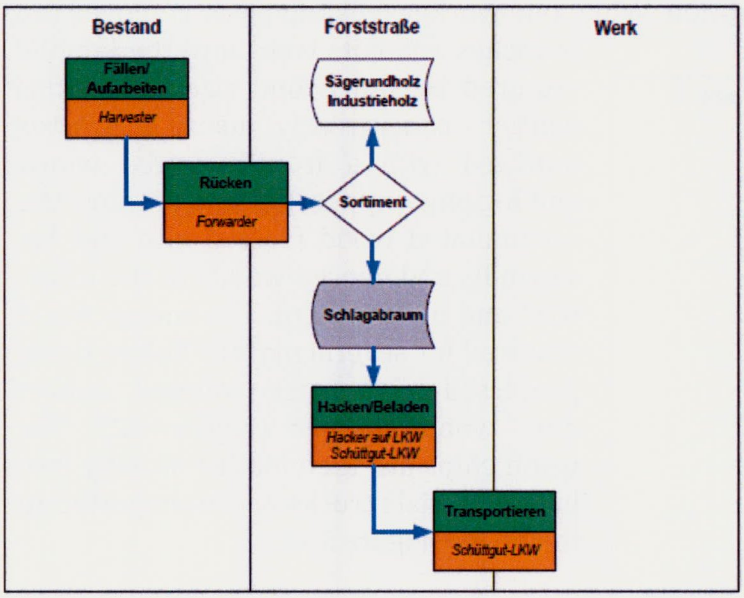


FIGURE 48: Harvesting with cable equipment/processor – chipping – transport with container truck

FIGURE 49: Logging residue is chipped and loaded directly into the container truck

2. *SORTED LOGGING RESIDUE RESULTING FROM HARVESTER USE – CHIPPING ON THE FOREST ROAD*

After felling and processing trees with a harvester, the sawmill logs, industrial timber and remaining logging residue (obtained during a separate process) are transported to the forest road with a forwarder and stored separately. The logging residue is chipped using a heavy-duty wood chipper and loaded directly into a waiting container truck (Figures 50 and 51).



The schedules for the transport vehicles must be coordinated in line with the productivity of the heavy-duty wood chipper. If too few trucks are available, the wood chipper will sit idle while waiting for them. If too many trucks are scheduled, they must wait for the wood chipper. Storing logging residues on the forest road requires large amounts of space.

Figure 50: Harvesting with harvester/forwarder – chipping – transport with bulk materials truck

Figure 51: Storage of logging residue alongside the forest road; chipping and loading directly into the prepared container truck

3. *Sorted logging residue/energy wood – chipping on the forest road*

Since logging residue generally yields insignificant quantities of material suitable for energy generation, additional volumes can be obtained through early top-trimming or using pulpwood or other low-grade wood. This also helps ensure that the capacity of the wood chipper is used more efficiently, which increases the overall cost effectiveness of the supply chain.

Aside from logging residue, energy wood from smaller-sized trees and other types of wood can also be used for energy generation. In such cases, two forestry workers must be dedicated to the harvesting operation. While one worker fells the trees, removes the branches and cuts trees into the lengths required by shortwood sizes, the other worker concurrently uses a tractor outfitted with a front-mounted winch and logging gripper/grapple to move the accumulated wood (sorted into logs for sawmills and energy wood) to the forest road and piles it there. The energy wood is stored for several months before being processed by a truck-mounted, heavy-duty wood chipper (Figure 52). The wood chips are then loaded directly into bulk materials trucks and transported to the buyer (Figure 53).

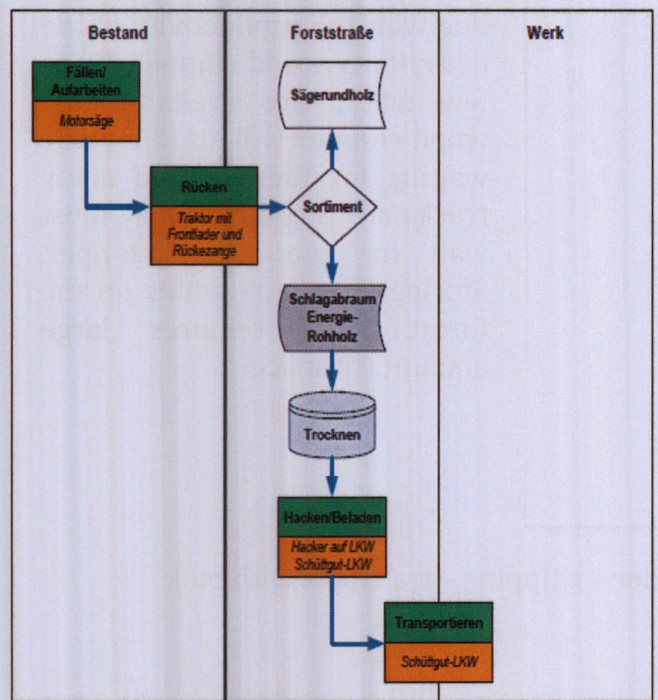


Figure 52: Harvesting with power saw and tractor/front loader/logging gripper – chipping – transport with bulk materials truck

Figure 53: Tractor with front-mounted winch and grapple (left); wood chipper Eschlböck Biber 80 (right)

4. *LOGGING RESIDUE – PRE-CONCENTRATION – CHIPPING AT THE STORAGE LOCATION*

After harvesting, extraction, transport and processing, the logging residue is left alongside the forest road and then transported to a nearby storage location (pre-concentration). In most cases, stanchion trucks without wall panels, stanchion trucks with steel-fenced compartments or stanchion trucks with wall panels are used for transport (Figure 54). Based on this pre-concentration approach, more chipped material is available at a given site, which means that the wood chipper's capacity is used more efficiently. At the storage location, the material is chipped into bulk materials trucks and transported to the heating plant (Figure 55).

FIGURE 54: Stanchion truck without wall panels, with steel-fenced compartments and with wall panels

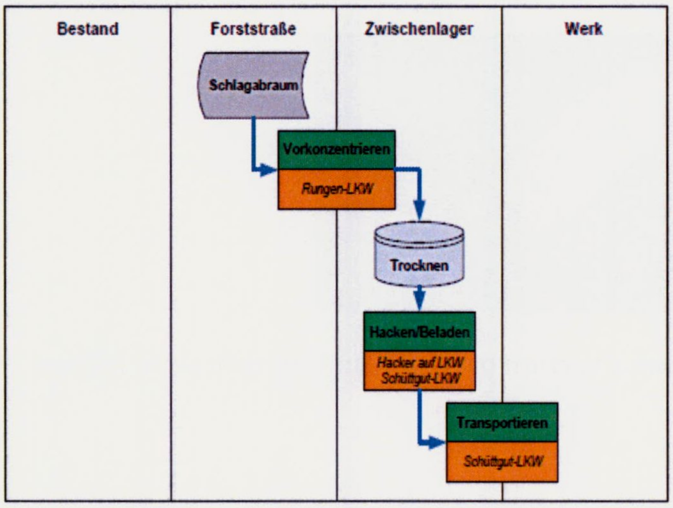


FIGURE 55: Pre-concentration of logging residue – chipping – transport with bulk materials truck

The shorter the transport distances prior to processing, the lower the associated costs. If there is sufficient storage capacity available on the forest road, transport of the raw material prior to processing should be minimised as much as possible.

5. *LOGGING RESIDUE – CHIPPING AT THE PLANT*

Logging residue can also be transported directly from the forest site to the heating plant, e.g. via container trucks. After a drying phase, the logging residue is chipped at the plant (Figure 56). On steep terrain, appropriate measures must be taken to prevent the biomass from sliding down embankments and onto the road. To make optimal use of container loading capacity, each layer of material loaded should be compressed with the loading crane (Figure 57). Of note, this process requires a wide area on the forest road to facilitate changing the containers and hitching/unhitching trailers.

Chipping at the heating plant using a mobile chipper should commence only after a volume of 1,000 to 1,500 stacked cubic metres of wood has been accumulated. This reserve helps to ensure the efficient use of the wood chipper's capacity.

After transportation to the plant, the material is stored and dried before being chipped. Upon commencement of the process, the material is fed into the chipper via an excavator, wood crane or skid loader.

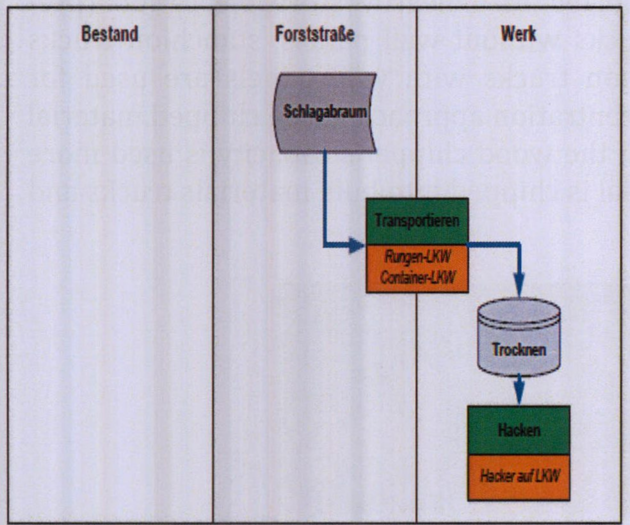


Figure 56: Transport of logging residue with container/stanchion truck – chipping at plant

Figure 57: Logging residue is compacted using a section of round timber; container is then unloaded at the heating plant

6. *LOGGING RESIDUE – BUNDLING – CHIPPING AT THE PLANT*

The bundling procedure was developed in Scandinavia and is at present predominantly used in Finland, with a high degree of success. After extraction, transport and processing, the logging residue is left alongside the forest road, where it is compressed into compact, cylindrical bundles with a baling machine (baler). The bundles, which measure 70 cm in diameter and 3 m in length, weigh about 500 kg. While bundle lengths may vary, they cannot exceed certain limits due to stability considerations. Transport to the heating plant is accomplished via a stanchion truck. After a drying phase in the forest or at the heating plant, the bundles are chipped at the plant (Figures 58 and 59).

When bundles of logging residue are stored alongside the forest road, impurities caused by rocks and dirt may present problems during the chipping process. For obvious reasons, such contaminants can cause premature chain saw wear. Because of this, shredders must be used to reduce the size of the wood. Secure or closed transport of the bundles is recommended as pieces of wood may break free during transport and cause problems. Storing bundles under tarpaulins or in covered areas significantly increases their dry matter content.

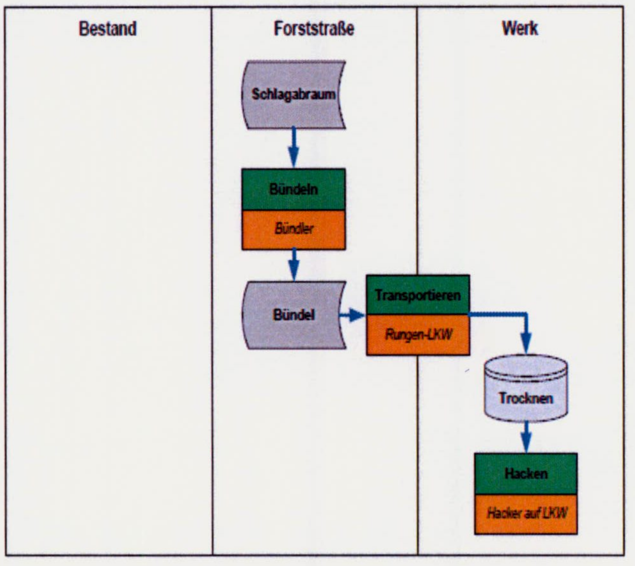


FIGURE 58: Bundling of logging residue – transport with stanchion truck – chipping at the plant


FIGURE 59: Bundling of logging residue

Securing a cost-effective and uninterrupted supply of forest wood chips as raw material for energy generation represents a major challenge for the future. The impact of the availability and distribution of this resource on supply chain costs cannot be underestimated.

7. *REFERENCES*

Kanzian, C., et al. (2006): Waldhackguterzeugung aus Schlagrücklass. Fallbeispiele im Laub- und Nadelholz. Projektstudie im Auftrag von Forst – Platte – Papier, Papierholz Austria und Stift Klosterneuburg; Universität für Bodenkultur, Wien.

Kanzian, C., Kindermann, G., Holzleitner, F., Stampfer, K. (2006): Regionale Energieholzlogistik Mittelkärnten, Universität für Bodenkultur Wien.

Kühmaier, M., Kanzian, C., Holzleitner, F., Stampfer, K. (2007): Wertschöpfungskette Waldhackgut. Optimierung von Ernte, Transport und Logistik. Projektstudie im Auftrag von BMLFUW, Land Niederösterreich, Stadt Wien und ÖBf AG. Insitut für Forsttechnik, Department für Wald und Bodenwissenschaften, Universität für Bodenkultur, Wien, 283 S.

IX. WOOD BIOMASS PRODUCTION IN LARGE-SCALE FORESTS

Prepared by: Dr. Johann Kremer (TUM)

For a special review we define large-scale forests as forests with an area of 20 ha and more. One can suppose that in those forests, surfaces of more than one ha extension of young stands (age 0 to 40 years) suitable for the production of biomass as wood energy, will occur with a certain frequency.
Calculations towards energy wood potential from young spruce stands in Bavarian private owned forests (> 20 ha) come to impressive figures. Based on a conservative estimation of only 20 % suitability of surfaces and an extraction rate of 70 loose cbm/ha there is a predicted potential of 376.000 loose cubic meters.

Looking at the production chain, one can easily detect that the younger the stands are, the extraction steps of felling and skidding will take more time compared to the chipping. At an age of 40 the time consumption, productivity and costs will be quite the same for chipping and for extraction. Given the fact that the feeling step is the most expensive, this operation should reach the highest possible productivity.

Beside the traditional chain saw harvesting option, on adequate surfaces, productivity considerations will open the field for skidders, **harvesters and forwarders** as special machines equipped with **feller-buncher**-heads. GINGRAS(2004) found out that there is an increase in productivity of 21 to 33 % for feller-buncher-heads compared to conventional harvester heads. Recent studies come to a performance level of 2,5 - 4,4 loose cbm/h which is much higher than expected.

The board of trustees for forest work and technology (KWF) is holding a market survey of feller-buncher units, which can be very helpful as a decision support for contractors but also for planning staff in wood biomass harvesting. The survey is available at: www.kwf- online.org/fileadmin/markt/10_faeller_buendler/faeller_buendler.html.
According to this survey the prices of feller-buncher heads are within a range of 8.000.- to 60.000.- €, at somewhat the half of a common harvester head. These assemblies enable harvesting contractors and entrepreneurs to enlarge their business segment or to establish a new one.

Another alternative could be the use of harwarders. Studies of BODELSCHWING and PAUSCH(2003) revealed that there are only few cases, which will end up with positive economic effects. Only if the surfaces and the extracted amounts of wood are minor, the combined machine is in advantage compared to the classical two- machine system, due to machine transfer and organization costs.

Even though productivity figures show the economic benefit of the feller-buncher-technic the steering parameter for net surface revenues will always be the price of chips. Looking at the demand of the last years and the prognoses of new investments towards targets in energy politics one could expect a positive development of prices (CARMEN, 2010). A positive development of energy wood prices is causing better net surface revenues and this will increase chances for the establishment of mechanized tending interventions and thinning operations in small-sized wood stands. When dealing with the marketing of chips there is an absolute need to analyze the whole process chain from the stand to the plant or to the boilers. Achieved profit margins in individual process steps are no guarantee for a profitable overall outcome. Even if the harvesting operations end up with positive profit margins chipping and transportation costs can impede the economic success.

A. References

GINGRAS, J.-F. (2004):
Early Studies of Multi-Tree Handling in Eastern Canada. International Journal of Forest Engineering. Vol. 15 No. 2 March 2004.

KWF, KURATORIUM FÜR WALDARBEIT UND FORSTTECHNIK E.V. (2010):
Marktübersichten. Maschinengruppe Aggregate. Homepage des KWF: www.kwf-online.org

v. Bodelschwingh, E., Pausch, R. (2003):
"Harvester und Forwarder in einer Maschine, der Harwarder Valmet 801 Combi im Praxistest"
„Harvester and forwarder in one machine, the harwarder Valmet 801 Combi in a practical test"
LWF-aktuell, 39, S. 23-26

ZIMMER, B.; WEGENER, G. (1996):
Stoff- und Energieflüsse vom Forst zum Sägewerk. Holz Roh Werkst. 54, 4: 217-223.

ZIMMER, B. (2009):
Ökobilanzierung der Bereitstellung von Waldhackschnitzeln. In EBERHARDINGER, A.; WARKOTSCH, W.; ZORMAIER, F.; SCHARDT, M.; HUBER, T.; ZIMMER, B. (2009): Prozessanalyse und Ökobilanzierung der Bereitstellung von Waldhackgut. Schlussbericht. Lehrstuhl für Forstliche Arbeitswissenschaft und Angewandte Informatik der TU München. Freising, 2009. 165 S.

ZORMAIER, F.; SCHARDT, M.; HUBER, T. (2009):
IST-Analyse und Stärken-Schwächen-Analyse der Bereitstellung von Waldhackgut zur thermischen Verwertung. LWF Bayern. In EBERHARDINGER, A.; WARKOTSCH, W.; ZORMAIER, F.; SCHARDT, M.; HUBER, T.; ZIMMER, B. (2009): Prozessanalyse und Ökobilanzierung der Bereitstellung von Waldhackgut. Schlussbericht. Lehrstuhl für Forstliche Arbeitswissenschaft und Angewandte Informatik der TU München. Freising, 2009. 165 S.

X. BIOMASS PRODUCTION FROM NON-FOREST LAND

Prepared by: Massimo Negrin, Valter Francescato (AIEL), Pablo Rodero, Juan Jesús Ramos (AVEBIOM)

A. OLIVE TREE PRUNING

1. *ORIGIN OF THE OLIVE TREE*

The olive tree is native from a wide geographic area which extends from the southern Caucasus to the highlands of Iran, Palestine and the Syrian Coast. From there it spread to Anatolia and Cyprus via Crete to Egypt, populating all the countries bordering the Mediterranean. Nowadays they are also grown in America, Africa, China, Japan and Australia. Its habitat corresponds to a Mediterranean climate which are regions characterized by long and dry summers. These regions are concentrated between latitudes 30 º and 45 º in both hemispheres (Civantos, 2001).

We must emphasize the importance of olives in the Mediterranean area, where almost 99% of the global is dedicated to this crop (estimated at almost 9.4 million hectares) (Civantos, 2001). The economic and environmental importance of this crop is obvious in the Mediterranean region. Because of its great aptitude of adaptation to this kind of weather, in some areas is almost the only one crop alternative and even it has colonized, over the centuries, many spaces replacing or accompanying the natural vegetation consisting of wild olive trees, junipers and mastic (Gonzálvez, 2002). In the Mediterranean forest the olive tree exercises other important environmental functions as protecting these areas from erosion and being a key element of the ecosystem, which is associated with lots of wildlife, especially in winter, providing food and shelter for certain animal species.

FIGURE 60: Olive tree in Andalucía

a) Spanish reality

Nowadays, olive groves are also a largely cultivated crop in Spain and they cover 2,23 Mha of agricultural land. The biggest extension of this crop is in the region of Andalucía covering about 1,400.000 Mha that means the 16% of the autonomous community of Andalucía surface and the 32% of the region's agricultural surface. Highlights the province of Jaen, where the olive has become a monoculture, covering 85% of agricultural land. Mostly, the olive grove is dedicated to the production of oil and in smaller proportion for table olives.

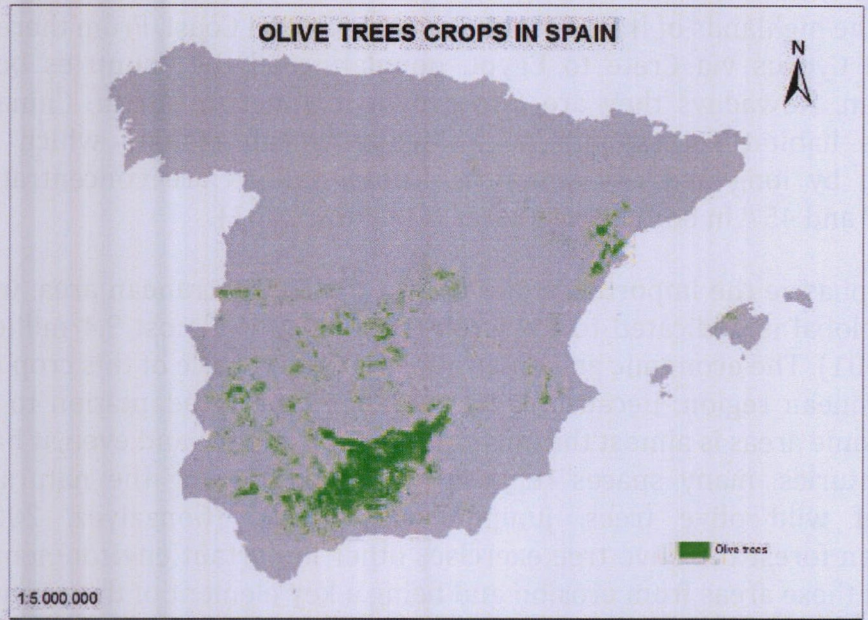


FIGURE 61: Distribution of olive tree crops in Spain

b) Italian reality

According to recent surveys (ISTAT, 2011), nowadays in Italy almost 1,2 Mha of olive tree crops are cultivated. The biggest extensions of stands are located in the southern regions, where site conditions are the more suitable to growth this crop.

In Puglia, Calabria and Sicilia regions olive trees cover 734.400 ha, about 61% of total olive tree surface in Italy. In Puglia more than 19% of regional surface is covered by olive tree stands. These crops are mostly dedicated to oil production and in smaller amount are addressed to table olives.

Region	Surf. Olive tree (ha)	Relation Surf. Olive tree/regional surf.
PUGLIA	377.550	19,32%
CALABRIA	194.887	12,80%
SICILIA	161.967	6,27%
TOSCANA	96.864	4,21%
LAZIO	88.577	5,14%
CAMPANIA	73.391	5,37%
ABRUZZO	44.086	4,07%
SARDEGNA	36.335	1,51%
BASILICATA	31.350	3,11%
UMBRIA	27.847	3,29%
MOLISE	19.974	4,48%
LIGURIA	16.820	3,11%
MARCHE	9.573	1,02%
VENETO	5.007	0,27%
EMILIA-ROMAGNA	3.637	0,16%
LOMBARDIA	2.425	0,10%
TRENTINO-ALTO ADIGE	386	0,03%
FRIULI VENEZIA GIULIA	108	0,01%
PIEMONTE	100	0,00%
VALLE D'AOSTA	0	0,00%
total	1.190.884	

TABLE 11: Olive tree crop area in Italy, divided per regions

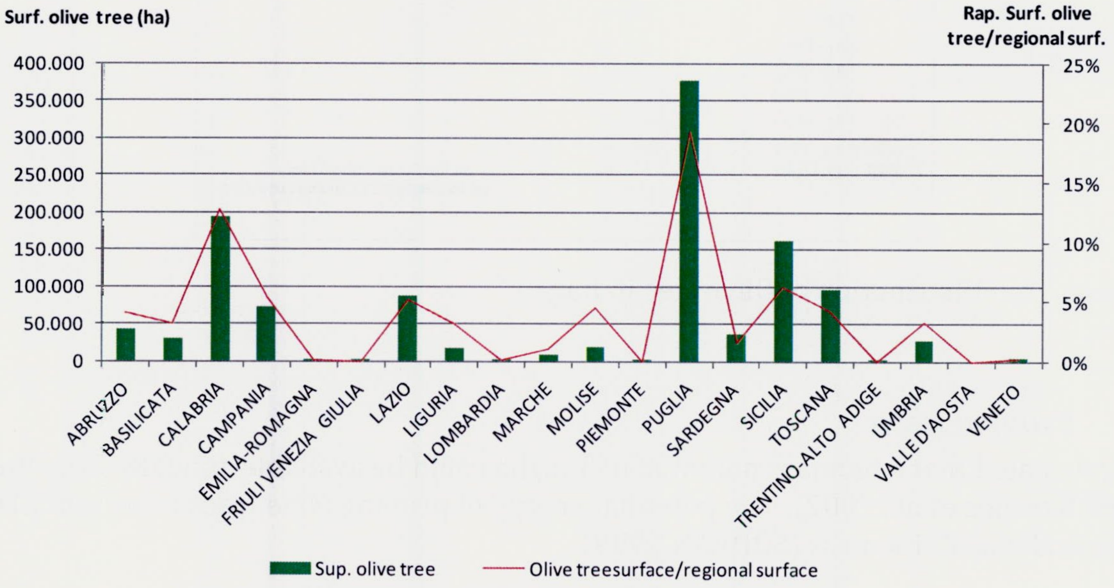


FIGURE 62: Olive tree crop area in Italy, divided per regions

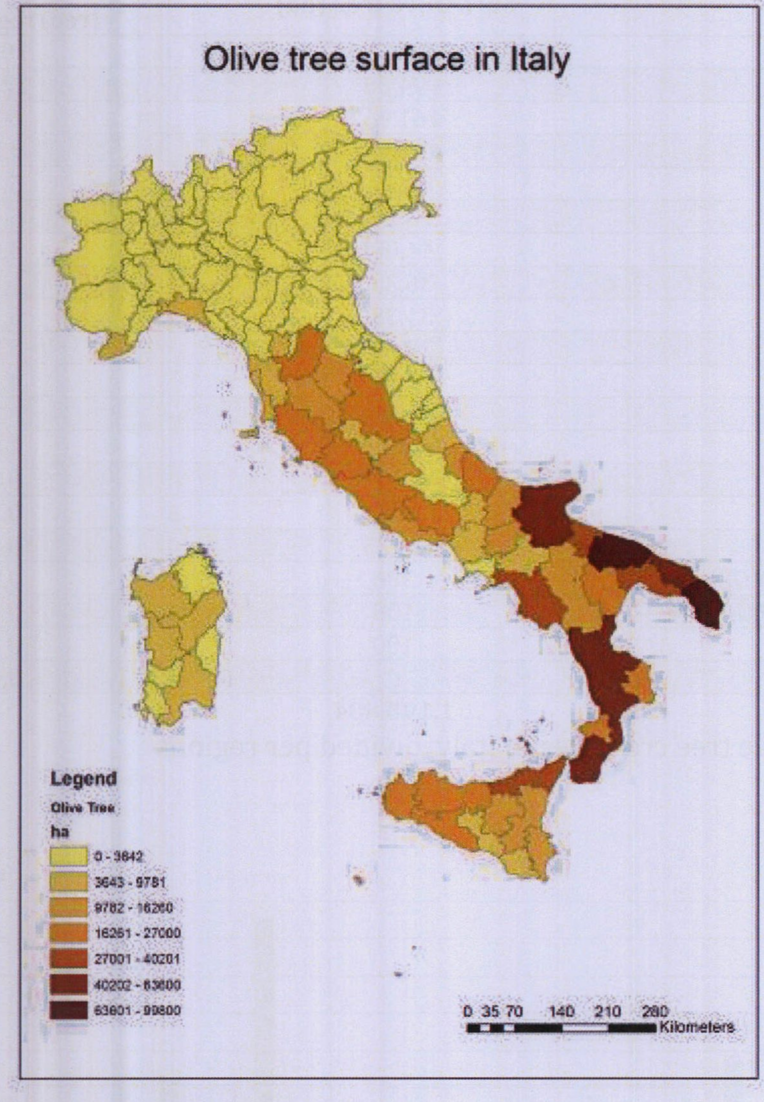


FIGURE 63: Distribution of Olive tree in Italy

2. *PRUNING YIELD*

It is calculated that a biomass potential of 3 tn/ha could be available annually from these crops (Sanchez et al., 2002). The potential energy of pruning olive trees represents 16% of the Andalucía's biomass (SODEAN 1999).

OLIVE TREE PLANTATION 1 ha	→	Olive Tree Pruning 3 tn	Fire Wood	0,7 tn
			Leaves	0,8 tn
			Branches	1,5 tn

FIGURE 64: Production of olive tree pruning and its parts

In Spain, the scenario today is that only around 5% of the olive tree prunings are being used as fuel. That means we are losing millions of tons of biomass and consequently a big income for owners.

In the following table we can see that there is a big potential of this kind of biomass in Europe, mostly concentrated in the Mediterranean region, the potential tons (using the factor 3 tons/ha we have seen previously) and approximate number of employments that could be generated if the whole quantity were used.

Country	Surface (Ha)	Tons	Potential employments
Spain	2.230.000	6.690.000	500.000
Italy	1.200.000	3.600.000	240.000
Greece	850.000	2.550.000	170.000
Portugal	400.000	1.200.000	80.000
Europe	4.680.000	14.040.000	1 mill
World	11.000.000	33.000.000	3 mill

TABLE 12: Potential tons of olive tree pruning and potential employments

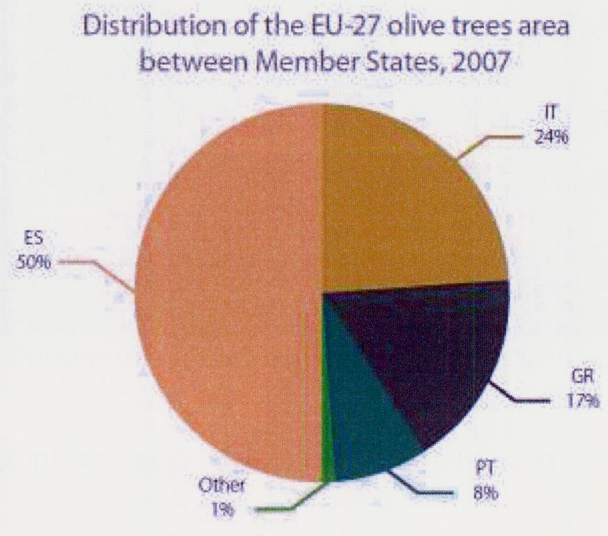


FIGURE 65: Distribution of olive trees area in EU

3. *OLIVE PRUNING CHARACTERISATION*

Elemental analysis

As we can see, the ash in the olive tree prunning is not so high as expected but this parameter can vary with the quantity of leaves introduced with the chips and of course, with the collection method. As we will see, depending on the collection method some sand can be introduced an therefore ashed can be increased.

Another parameter that can increase a lot depending with the process is the moisture. If we collect biomass and the beginning of the winter and we carry it directly to combustion it will be very wet (30% or more). If we let it dry on the field or we dry by moving and exposing to the sun in the stockyard it can increase its Net Calorific Value drastically (see next table).

Parameter	Dry	Average	Wet
Moisture %	10,95	20	30
Ash as received%	1,55	1,39	1,22
Volatile matter as received%	72,83	65,43	57,25
NCV as received (Kcal./Kg.)	3.769	3.330	2.845

TABLE 13: Elemental analysis of olive tree prunning

4. *BIOMASS COLLECTION TECHNOLOGY*

Mostly, once deposited on the ground, these prunings were usually piled and burned directly in the fields.

FIGURE 66: Olive tree prunning being burned for its elimination

Olive trees are usually pruned once every two years to improve the state of the plantations.

The chain of the olive tree prunings can be schematized as follows:

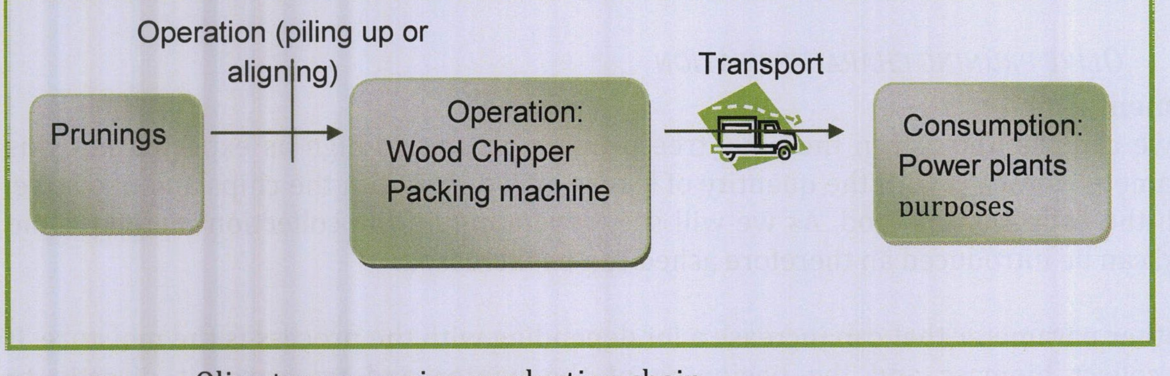


FIGURE 67: Olive tree prunning production chain

a) Piling up or aligning operation

Before collecting the olive tree pruning it's necessary to make a previous labor that can be done in two different ways. Olive tree pruning can be piled up or aligned. Piling up operation cost is lower but after being pulled, biomass is littered with sand.

FIGURE 68: Piling up olive tree pruning

FIGURE 69: Aligning olive tree pruning

Figure 70: Aligned olive tree pruning

b) Chipping or packing operation

One of the options for the exploitation of olive tree prunings is charging them to a transport vehicle for further pre-processing at the plant. The main drawback of this system is the low density of biomass, which results in higher transport costs and a need of yard for the storage and also the low performance rates. The main advantage of processing the biomass into a storage point is that the costs are lower; since performance rates are higher and the machines' operating costs are lower (staff, maintenance, electricity, etc ...).

Nowadays, the most common procedure is to chip the olive tree pruning in place with a chipper machine. Lately there are some machines have come up specially adapted to this kind of biomass.

FIGURE 71: Manual charging of olive tree prunning

(1) Field chippers

Depending on the chipper machine's feeding system they can be divided into two categories:

Manual feeding chippers. There are various machines on the market of this kind. They have a "chimney" to direct the chips to a container. The investment is small but the performance rates are very low because it depends on the staff who feeds the machine.

FIGURE 72: Manual feeding of a chipper machine

- **Chipper machines fed by an octopus.** Once the biomass has been piled up or aligned, the machine moves to the piles where the biomass is fed quickly by means of an octopus. There are several of these machines in the market and the performance rates are high.

- **Auto-feeding chipper machine**. Previous alignment of the biomass, these kind of chipper machines can collect the olive tree pruning from the field.

Figure 73: ATILA, S-180-Biomasa chipper machine

Figure 74: SAT-4 chipper machine

(2) Packing Machines

Lately there has been a development of new machines on the market which technology allows packaging the olive tree pruning at the field. The packing operation is done by compacting and shaping the material. The density of the material can rise up to 0.7 tn/m3. This action allows reducing transport costs and storage space.

FIGURE 75: Trabisa's baler machine

In Spain, Trabisa has developed a self-propelled machine, capable of feeding and packing all types of woody materials, based on previous model.

FIGURE 76: Self propelled baler machine (Lerda)

5. *COLLECTING COSTS*

The olive tree pruning is a biomass which its elimination means a cost for the producerr, so if the producer instead of spending on removing this biomass as a residue, invest in machinery to value and sell this biomass can turn an expense into an income.

The following table details the most common removal costs of the biomass according to several sources consulted:

Source	Biomass	Removal method	Observations
CIRCE	Average elimination costs: 1448 €/ha 37,8 €/t	Including thinning (removal of trees) and residues removal (apiled and chipped)	Silvicultural treatments cost average in Aragón.
ECAFIR / Gavarres (Girona)	Average bush elimination, thinning and prunning,: 2.000 €/ha 50 €/t	Bush removal, selection and tree removal, low braches removal. Apilation of residues.	High value, but quite representative because costs in Catalonia in a relatively close area, and it was consulted with industry experts to perform such tasks.
SODEAN (Andalucía)	Elimination costs: 658,7 €/ha 34,9 €/t	Manual apilation of residues and burn. Manual apilation of residues and chipping.	According to this source, in the case of recovery of the forest biomass, the forest owner can save half the cost of the removal.

Source: Avebiom's elaboration from several sources.

TABLE 14: Cost comparative as per several studies

In the next table we can see different prices of chipper machines:

BRUKS CHIPPER	JENZ CHIPPER
Pot.: 415 CV chipper+150 CV forwarder	Pot. 220 CV
Investment: 360.600€	Investment: 198.330 €
Yield: 16.000 kg/h	Yield: 9.000 kg/h

Source: SODEAN.

TABLE 15: Characteristic and investment for BRUKS and JENZ chippers

Handling and storage of packaged biomass is less difficult than if the biomass is chipped. If feasible, this seems to be the best system for collection, transportation and storage for the case of large supplies of woody biomass.

In the next table we can see two baller machines characteristics and invesment for its comparation.

TRABISA Baller	TIMBERJACK Baller
Pot.: 340 CV	Pot.: 172 CV
Investment: 216.364 €	Investment: 400.000 €
Yield: 10.000 kg/h	Yield: 11.000 kg/h

Source: SODEAN

TABLE 16: TRABISA and TIMBERJACK comparation

In the following table is detailed the hourly rate by the number of hours scheduled to work for each machine.

Process	Jenz Chipper	TRABISA Baller
Nº hours/year	1.400	1.400
Hourly cost (€/hour)	28,6	67,5
Traction cost (€/hour)	30,4	0
Total (€/hour)	**59,0**	**67,5**

Source: Manufacturer data

TABLE 17: Hour forecast for each machine and hourly cost (€/h)

6. *ENERGY USE OF OLIVE TREE PRUNING*

Nowadays, in Spain, it is important to note that today, the use of olive tree pruning is reduced to the environments of the thermal power plants where this biomass is used, and consequently a huge quantity is burned in the field to avoid diseases. This distance where it's profitable to collect the prunings can vary depending on the transport costs (varies with density, kind of roads, season, region), moisture (varies with the season, process) and the price the power plant is paying. That in the practical can mean a range between 75 and 150 km.

The main problems is that collection costs are high, high dispersion of this kind of biomass making unprofitable picking and producing energy with olive prunings. Also, the remuneration of energy in Spain is too low. The limiting factor is the rate that in Spain is regulated by Royal Decree 661/2007 which includes the pruning of olive trees within the group B.6.2. (Waste from agricultural activities). These fees established in Royal Decree 661/2007 were reviewed by the Ministerial Order OM ITC/3801/2008 to encourage the recovery of biomass.

GROUP	SUBGROUP	POWER	REGULATED RATE c€/kWh	REFERENCE PREMIUM c€/kWh	UPPER LIMIT c€/kWh	LOWER LIMIT c€/kWh
b.6	b.6.2	P < 2 MW	13,4216	9,2462	14,2107	12,9081
		2 MW < P	11,4817	7,0895	11,9472	11,0813

TABLE 18: Spanish electric fares for olive tree prunning (RD 661/2007)

These are the fees that a power plant company receives for using biomass but the prices that this company is paying obviously are different and they are not the same for all companies. These prices often vary with the moisture and they can start by 18 €/tn if the pruning are very wet (common in January, February) until 65 €/tn if the water content is very low.

POWER PLANTS	Share of Olive Tree Biomass	tn /year
El Tejar (Vetejar, Baena y Algodonales)	10%	32.000
Extragol	50%	30.000
Puente Genil	50%	34.000
Bioeléctrica de Linares	50%	50.000
Bioenergía Santamaría	10%	10.000
Fuente de Piedra	10%	6.000
Aldebarán Energía del Guadalquivir	60%	30.000
TOTAL		**192.000**

TABLE 19: Power plants consuming olive tree pruning

7. *BIOMASS POWERPLANT DISTRIBUTION*

Spain

In the following map it has been represented the distribution of the power plants that nowadays are consuming woody agricultural biomasses. As we can see, they are distributed along the olive trees crops because its main fuel is olive cake and olive tree pruning.

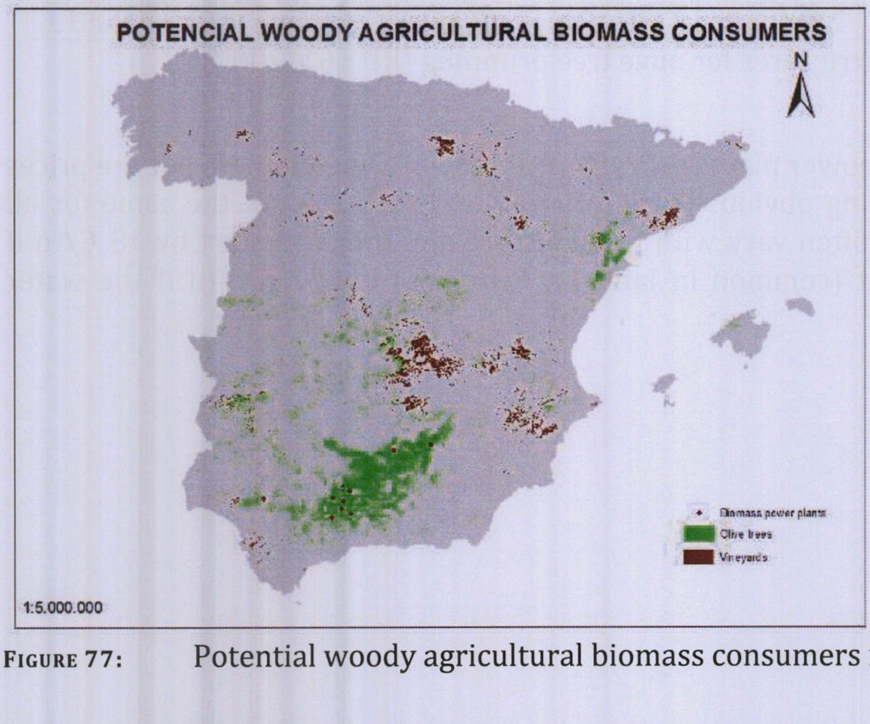


FIGURE 77: Potential woody agricultural biomass consumers in Spain

FIGURE 78: Olive tree pruning stockyards at a power plant

Italy

The following map shows the distribution of energy plants supplied with woody biomass. They are classified and distributed as follow:

- thermal plants are located mainly in northern Italy, in particular Veneto, Trentino and Friuli VG Regions;
- power plants are homogeneous distributed throughout the peninsula, the biggest plants (> 20 MWe) are located in the southern regions (Calabria and Puglia);
- CHP plants are more concentrated in north-eastern regions.

Must be stated that data available for distribution and characteristics of energy plants (thermal, power or CHP) in Italy, are actually not complete. Not for all regions was drawn up a complete database of plants and currently the main data available are collected for the north-eastern regions (Veneto, Friuli and Trentino). This fact partially justifies the different plants concentrations in the map.

In southern regions, where olive tree cultivations and power plants are both widespread, pruning are often addressed to supply big power plants, which is suitable to born this low-quality chips.

In the north regions other than power plant, this kind of "poor" biomass is used to supply also small CHP plants (< 1 MWe) and big district heating or chip boilers (> 1 MWth, moving grate technology).

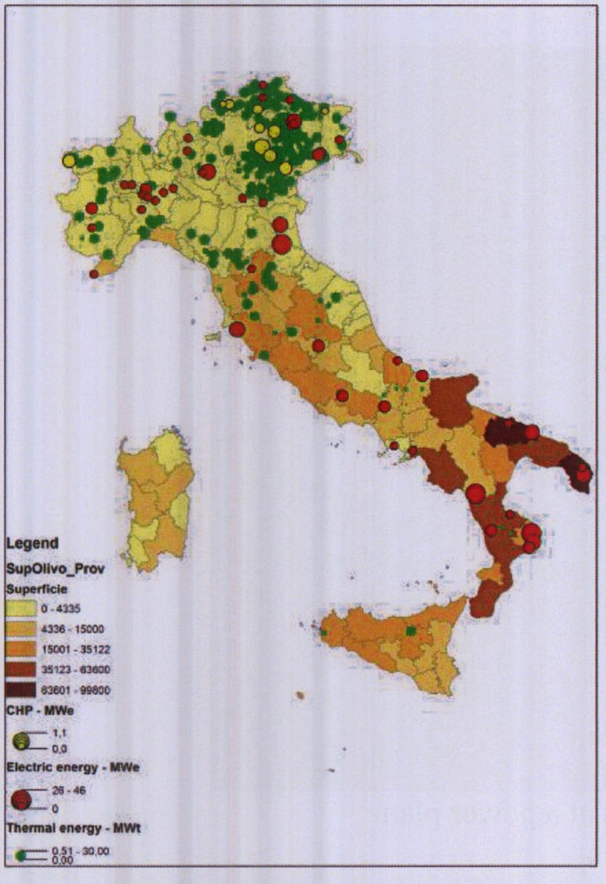


FIGURE 79: Biomass plants distribution and area covered by olive tree cultivation.

8. *STUDY CASE*

CHP Plant supplied with olive tree pruning – Calimera (Lecce, Italy)
<u>General description of site</u> - maximum energy output of CHP: 1 MWe - large square concrete for the storage of pruning - loading area located under the level of the point designated to receive the wood chips, that is moved by a mechanical shovel

Figure 80: Calimera CHP

Power plant

- Boiler: Uniconfort (1 MWe)
    - electric generator: Turbine HRS Turboden (ORC technology)
    - efficiency for electric energy production: 24%
    - temperature of water output: 30-35 °C
    - heating power input: 4.155 kW (winter) – 4.862 (summer)
    - total efficiency of plant: 90%

Figure 81: Calimera's boiler

- bag filters
    - average dust emission: 0,37 mg/Nm^3 (February 2011)

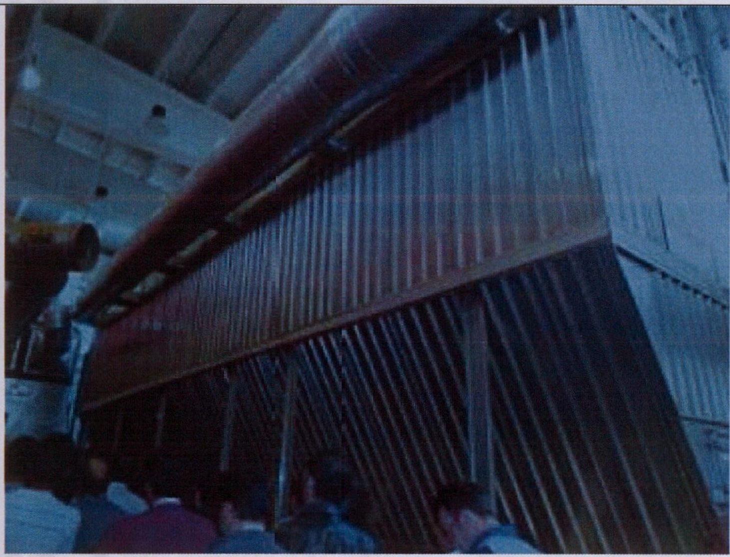


Figure 82: Calimera's plant

Supply:

- almost all material from olive tree pruning (major crop widespread in Puglia region)
- annual consumption of plant 8-10.000 t/year (Puglia has a potential availability of 2M t of biomass from olive tree pruning)
- two different supply systems of raw material:
  - o holders of plant manage the collecting of pruning, with own contractors, at olive tree field of farmers;
  - o payment of independent contractors with 30 €/t at the plant.

Oleicola el Tejar (Córdoba, Spain)

Company with several installations consuming olive tree pruning:

- Palenciana (Córdoba) has three boilers in the powerplants with: 12,6, 5,7 and 5,3 MW

Figure 83: Palenciana's powerplant

Baena (Córdoba) 25 MW

Figure 84: Baena's powerplant

B. Vineyards

1. *Introduction*

a) Italian reality

Italy is one of the oldest wine-producing regions in the world and one of the world's foremost producers, responsible for approximately one-fifth of world wine production (2005). Italy is the second largest wine producer after France and in 2008 it surpassed France for the title of world's biggest with nearly six billion liters of wine (Mulligan et al., 2006).

The National Institute for Statistics (Istat) estimate that in Italy there is a surface of 778.376 ha covered by vineyards cultivation (2010).

The largest area is present in the following regions: Puglia (146.177 ha), Sicilia (140.386 ha), Veneto (76.595 ha) and Toscana (62.425 ha).

FIGURE 85: Vineyard cultivation in Italy

Those expand surfaces could guaranteed an high availability of biomass from vineyard. Usually during winter time, branch of vineyards are release on the ground after the pruning operations: this material could be directed to an energy recovery after collecting, baling and chipping operations.
Wood chips produced using vineyard pruning can be effectively used for energy purposes in heating plants, for example, in wineries and tourism resort, replacing heating oil or LPG.

Following figure and table describe the surface distribution of vineyard crops in Italy and incidence related to regional surface.

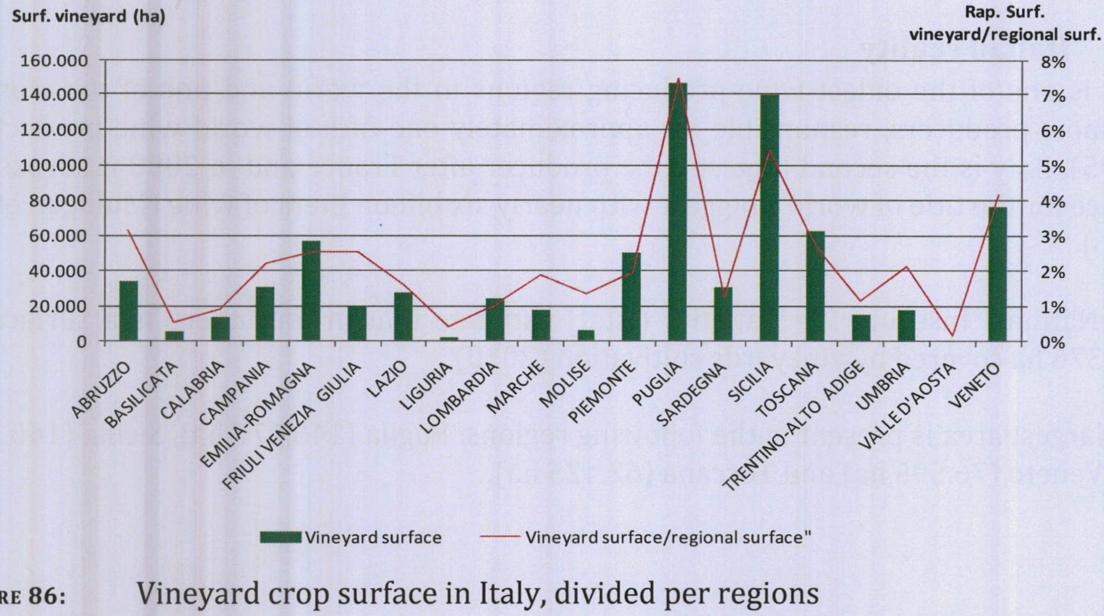


FIGURE 86: Vineyard crop surface in Italy, divided per regions

Region	Surf. Vineyard (ha)	Relation Surf. vineyard/regional surf.
PUGLIA	146.177	7,48%
SICILIA	140.386	5,43%
VENETO	76.595	4,16%
TOSCANA	62.425	2,72%
EMILIA-ROMAGNA	56.950	2,54%
PIEMONTE	49.898	1,97%
ABRUZZO	34.235	3,16%
SARDEGNA	30.844	1,28%
CAMPANIA	30.248	2,21%
LAZIO	27.323	1,59%
LOMBARDIA	24.451	1,02%
FRIULI VENEZIA GIULIA	19.901	2,53%
UMBRIA	17.991	2,13%
MARCHE	17.667	1,88%
TRENTINO-ALTO ADIGE	15.451	1,14%
CALABRIA	13.686	0,90%
MOLISE	6.005	1,35%
BASILICATA	5.361	0,53%
LIGURIA	2.282	0,42%
VALLE D'AOSTA	500	0,15%
Total	**778.376**	

TABLE 20: Vineyard crop surface in Italy, divided per regions

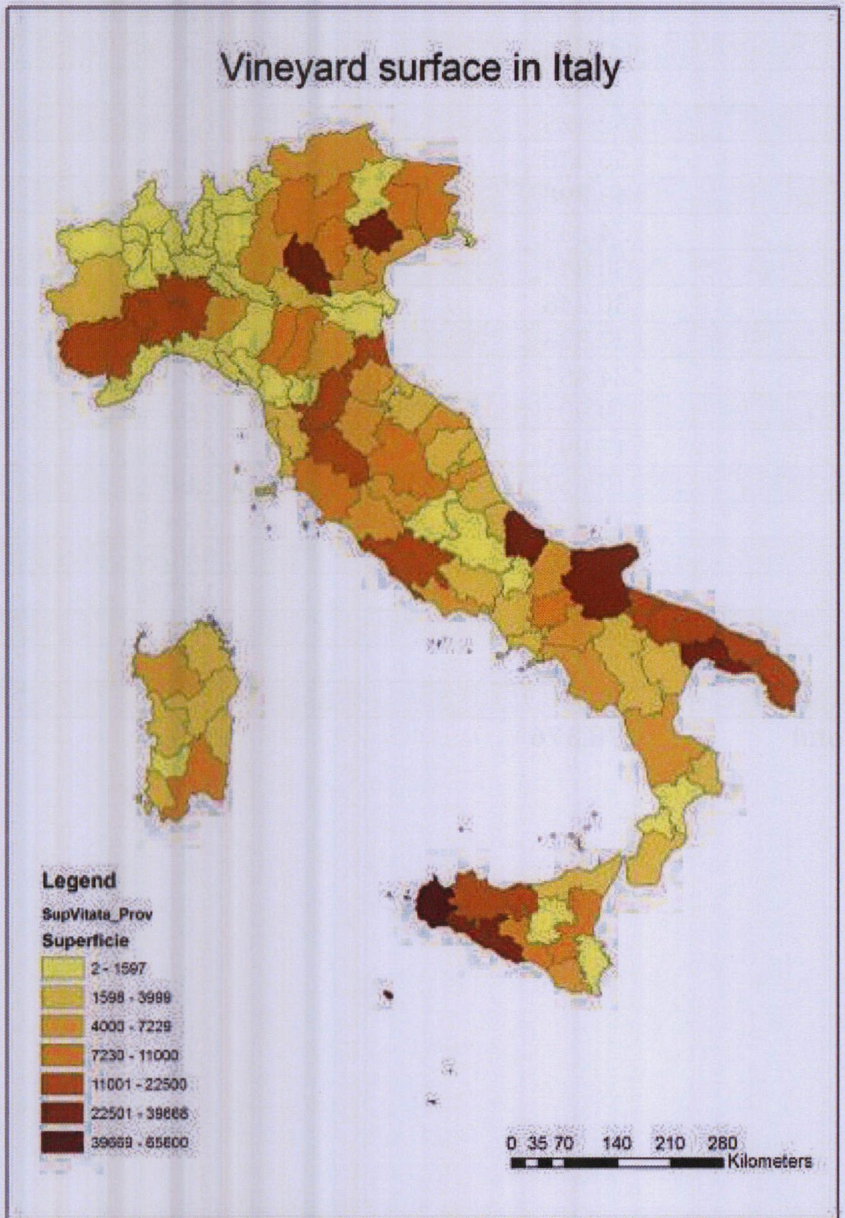


FIGURE 87: Distribution of Vineyards in Italy

b) Spanish reality

In Spain, vineyards only cover more than one million hectares, equal to 1/3 of the vineyard area in Europe. The largest vineyard area in Spain is located in the province Castilla-La Mancha and it covers a total area of about 530.000 ha, equal to 47% of the total vineyard area in Spain. In economic terms the vineyards in Castilla-La Mancha provides work to 25.000 people or 6 million work days per year. It was calculated that this vineyard region could provide 556.000 t/year of pruning residues that is equivalent to 2.119 MWh/year or 17 Gtep/year and it would save 545.000 tCO2 per year (Data elaborated by Avebiom from the Ciudad Real's wine register data). If these values are upscaled to the entire vineyard area in Spain, the energy provided by pruning residues from vineyard could provide a total amount of energy equal to 3.877 Tcal/year.

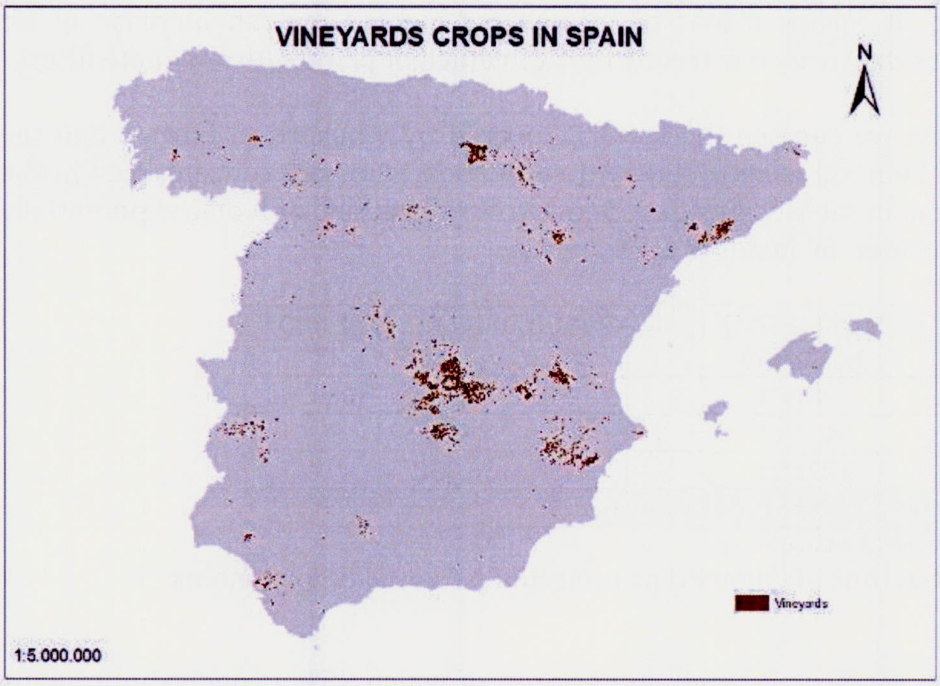


FIGURE 88: Distribution of Vineyards in Spain

2. *PRUNING YIELD*

It is calculated that about 1,5-3 t/ha of pruning could be annually available from vineyard crops (Francescato et Antonini, 2011; Cavalli et al. 2011), but the energy potential is actually used in minimal portion.

The problems for development of supply chain are actually linked to common knowledge of technologies for collecting and final energy use of this biomass in adequate plants.

However machines for collecting and chipping vineyard pruning are tested and largely available in the market, so like the plants for energy use.

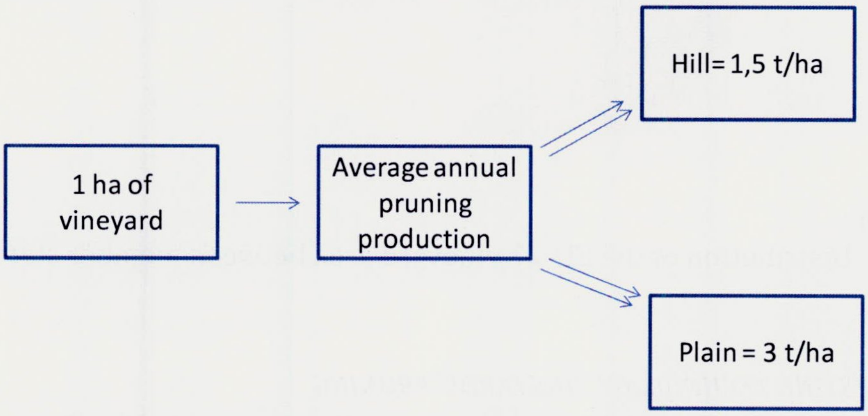


FIGURE 89 Production of vineyard pruning – ton per hectare – 45% water content

In Italy every years are lost millions tons of biomass, that usually are open burnt in yards after pruning. It means a loss of income for owners and an increase of air pollution, because residual are no correctly burnt in efficient plant with adequate filters.

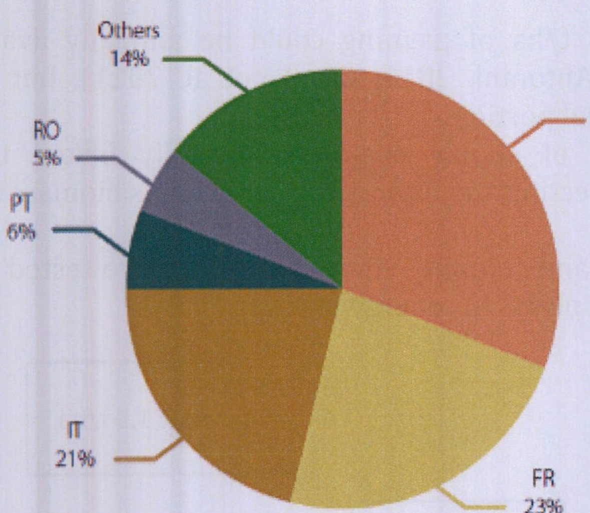
In the following table we can see the surface covered by vineyard in Europe and the great availability of biomass (tons). Vineyard cultivation is mostly concentrated in the Mediterranean region; in table X it's possible observe the volume of biomass potentially available using the prudential factor of 1,5 tons/ha.

Country	Surface (ha)	Potential biomass *1.000 t
Spain	1.160.000	1.740
Italy	778.376	1.170
France	842.000	1.263
Portugal	233.000	350
Europe	3.710.000	5.565

(Eurostat 2007; ISTAT 2010 (Italian data))

TABLE 21: Potential tons of vineyard pruning and potential employments

The vineyard area in EU-27 is 3.7 million hectares, of which 95% is dedicated to wine production. The European Union is the largest wine production region in the world. Within EU-27, Spain represents 31% of the total vineyard area; Italy amounts to about 21%.



(Eurostat 2007)

FIGURE 90: Distribution of the EU-27 vineyard area between member states

3. *HARVESTING TECHNOLOGY VINEYARDS' PRUNING*

There are several logistics solutions for the collecting and energy use of vineyard pruning: after first aligning of pruning, it's possible chipping the raw material in field or having a packing before the final chipping in the storage deposit and final energy use.

Three main methods for collecting and initial processing of pruning are individuated. Following are illustrated different phases of three methods individuated in the energy recovery of vineyard pruning:

1. chipping post collecting. The main advantage of processing the biomass into a storage point is that the costs are lower; since performance rates are higher and the machines' operating costs are lower (staff, maintenance, electricity, etc ...):
   - disposal of pruning in the middle of the spin;
   - first pass with the collecting and balling machine;
   - transport out of the land-plot or to a logistic platform for the storage of entire material (in bale);
   - storage of packs into a platform, covered with a sheet or outdoors;
   - wood chipping of bale with specific chipping machine and stock indoor;
   - conferment of wood chips to plants.

FIGURE 91: Vineyard alling machine (Gallignani Rotoballer)

2. chipping in field (in-line):
   - disposal of pruning in the middle of the spin;
   - pass with collecting-chipping machine in a spin;
   - discharge of chipped material in a tractor with trailer, allocated in the adjacent spin, in line with collecting-chipping machine;
   - conferment of wood chips to deposit or plants.

FIGURE 92: Vineyard chipping machine with chimney to a container

3. chipping in field (single machine):
   - disposal of pruning in the middle of the spin;
   - pass in a spin with collecting-chipping machine equipped with an own tank for collection of wood chips;
   - discharge of chipped material in a tractor with trailer, allocated out of the field;
   - conferment of wood chips to deposit or plants.

Figure 93, Figure 94, Figure 95, Figure 96: Different machinary for collecting vineyard's biomass. Vineyard collected into a box or a bag, lead by the machine and after download in a trailer in the headland when full. Machines: Berti (up left); Futura (up right); Nobili (down left); Marev Trinciator (down right).

4. *PILING UP OR ALIGNING OPERATION*

Before collecting and/or chipping the vineyard pruning, it's necessary to make a previous labor of aligning that can be done with specific machine, adequately large to pass among the fills of vineyard.

Figure 97: Vineyard prunning aligned

a) Packing operations

The packing operation is done by compacting and shaping the material. Lately there has been a development of new machines on the market which technology allows packaging the vineyard pruning at the field. To optimize the collection phase, the collecting and packing machine must be able to operate in the middle of rows (2,40 m inter-row).

Those are the phases that constitute packing operations:

- step forward the tractor with the packing machine advances along the row picking up the pruning;
- ligation phase: when the filling of the compression chamber and the compression of the material is completed, the tractor stop for tying;
- discharge phase: the end stage of ligation proceed with the unloading of the bale. The stage ends with the restart of packing operation along the row;
- turned round phase: consider the maneuver performed between row.

In Italy a packing machine is being developed with compression chamber to fixed-volume, adapt to use into vineyards. These are the main features work of this kind of machine:

- width of packing machine: 2,40 m;

- packs dimension:
    - o Diameter: 1,5 m;
    - o with: 1,2 m.

Data about vineyards pruning collecting:

- weight: 470-500 kg
- density: 200-240 kg/m^3
- packing productivity: 6 t/h (W 50%)

(Cavalli e Grigolato, 2010)

FIGURE 98: Vineyard prunning balling machine

b) Chipping operations

There are some machines adapted to chipping vineyard pruning as it is, or pruning in Packs. Chipping operations depends on the characteristics of machine's feeding system; three main categories can be individuated:

- chipping machine with a large opening, able to work packs with fields up described.

FIGURE 99: Chipper with big feeding opening

It could be used also a conventional chipping machine (with a small opening for material alimentation), with disadvantage that great packs can't be chipped without opening of these.

- Chipper machines with chimney for expulsion. Once the biomass has been piled up or aligned, the machine moves to the piles where the biomass is fed. After feeding it's chipped and expulsed with a chimney in a trailer (attached to a tractor or the same machine).

FIGURE 100: Chipper machine with chimney

- Auto-feeding chipper machine. Previous alignment of the biomass, these kind of chipper machines can chips and collect the vineyard pruning from the field.

FIGURE 101, FIGURE 102: Chipping machine Nobili TRP 145 - RT

5. *COLLECTING COSTS*

Production costs of woody biomass fuel from vineyard pruning is variable and it depends on logistic of the yard and so on different parameters as:

- collecting and handing in field technique;
- transport distance of raw material;
- wood chipping operations;

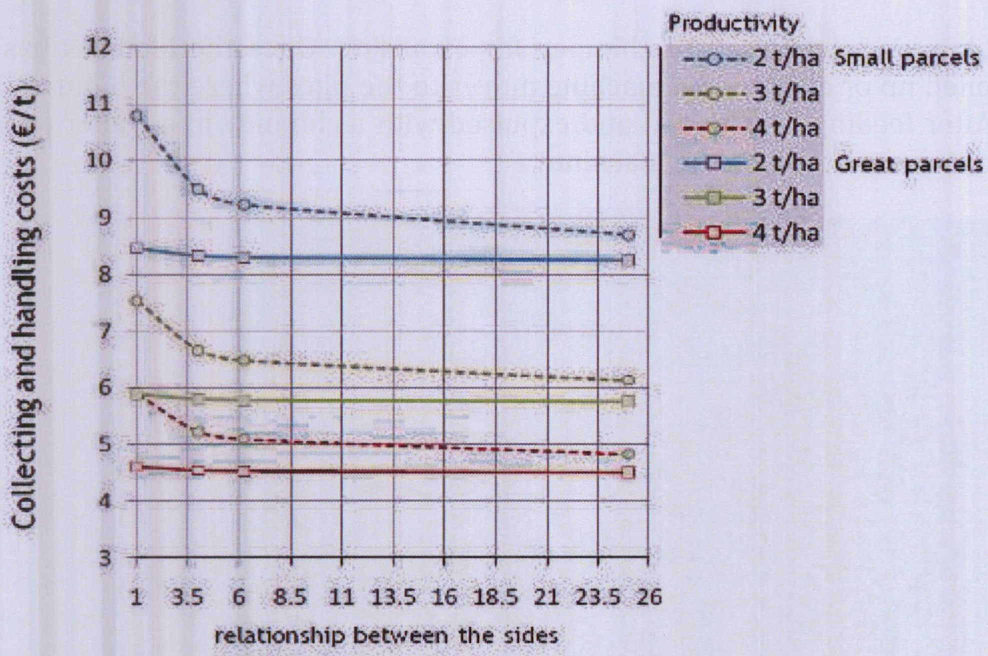


FIGURE 103: Cost of collecting and handing in field (Cavalli et al., 2011)

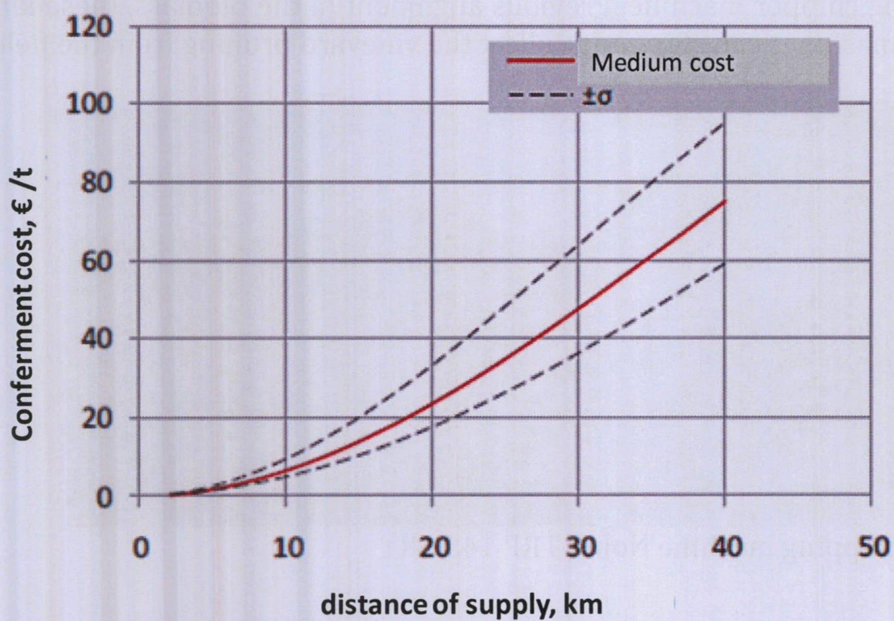


FIGURE 104: Cost of transport (Cavalli et al., 2011)

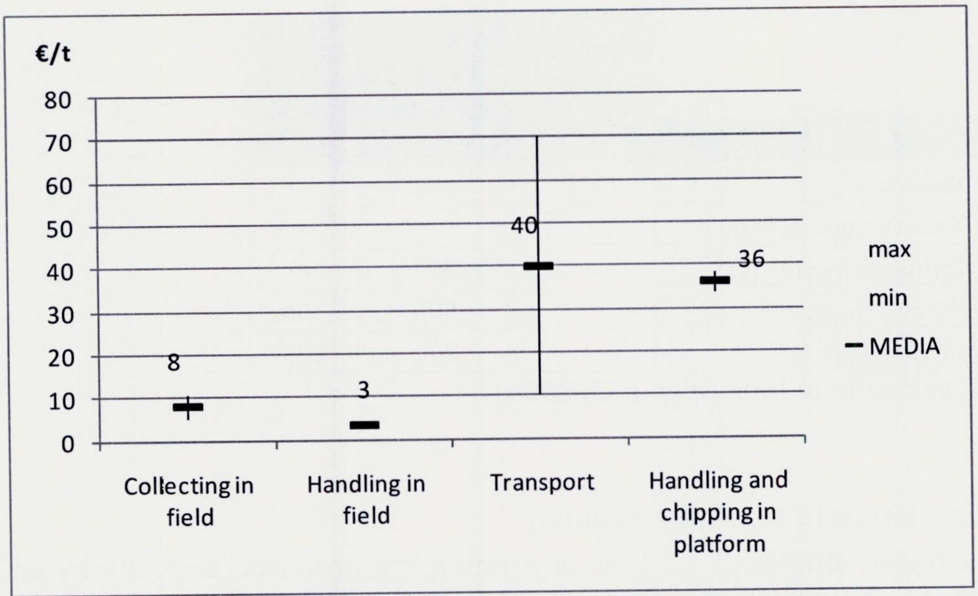


Figure 105: Total production cost (AIEL elaboration, 2011)

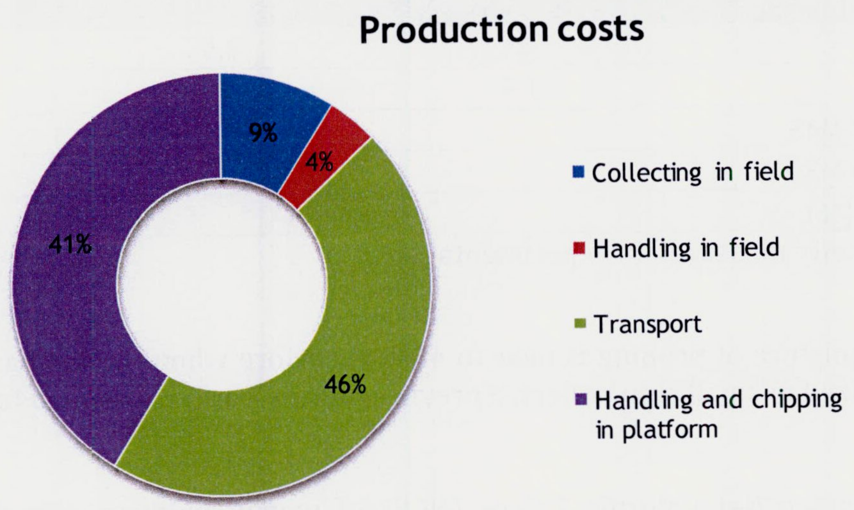


Figure 106: Total production cost (AIEL elaboration, 2011)

The total production costs for woody waste collecting is variable between 52 and 120 €/t. It depends on logistic of collecting and transforming system and machinery adopted.

6. *ENERGY USE OF VINEYARD PRUNING*

In Italy woody biomass coming from vineyard is classified as vegetal material produced from pruning, potentially addressed to energy use in biomass plant (Dlgs 205/10). This woody material is not consider as waste or a by-product, only transport document is necessary for supplying it to the plants. Emission limits of emissions are fixed in a national decree (see table X).

	Thermal power installed		
	35-150 kW	150-300 kW	3-6 MW
Emission (dlgs 152/2006)	mg/Nm3		
Total dust	200	100	30
Total Organic Carbon	-	-	-
Carbon monoxide (CO)	-	350	30
Nitrogen oxides	-	500	500
Sulfur oxides	-	200	200

TABLE 22: Limit emission in Italy (dlgs 152/2006)

7. *NET CALORIFIC VALUE OF VINEYARD PRUNING*

According to some recent studies, 2-4,5 tons of pruning are produced annually by an hectare of vineyard; 1,5-3 of which are effectively harvested by machines, producing, in some cases, a maximum loss of 25% (Spinelli et al., 2011).

Productivity M45	t/ha/y		
Total yield	2		4,5
Net yield	1,5		3
Average net yield M45		2,3	
Average net yield M30		1,8	
Maximum losses (%)		25%	

TABLE 23: Productivity measured in experimental tests

At harvest time the moisture of pruning is near to 45%, therefore when the biomass is addressed to be valorized in small chip boilers, a previous drying period is needed to get a 30% of moisture.

The next table shows the Net Calorific Values (NCV) of woody biomass, based on different moisture (M) level:

Moisture (%)	NCV (kWh/kg)
12%	4,4
30%	3,4
45%	2,5

TABLE 24: NCV for different water content

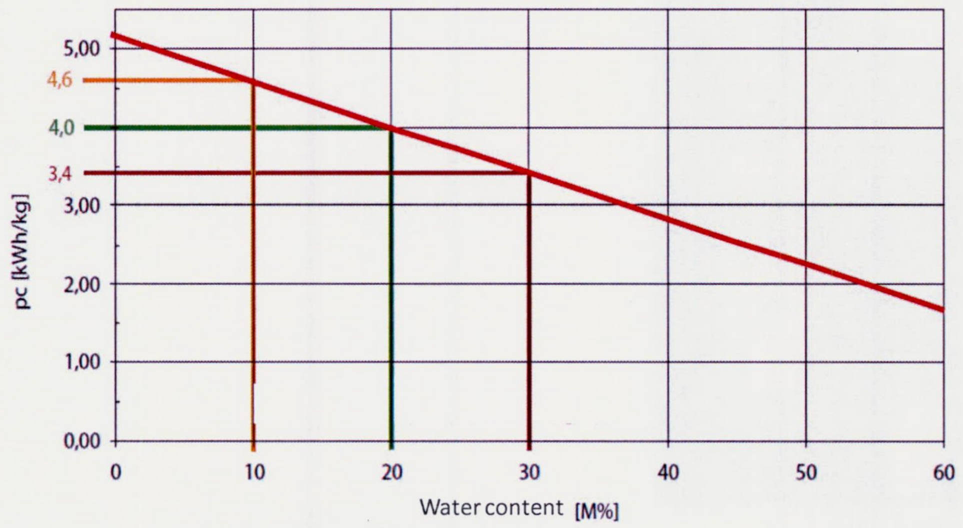


Figure 107: NCV for different water content.

Considering a NCV of about 3 kWh/kg (M30), **one hectare** produces yearly about **5,4 MWh of primary energy**.

8. *Chemical characteristics of wood chips from vineyard pruning*

Vineyard pruning are characterized by an ash content higher than untreated wood. Normally it's possible obtaining an ash content of 3,85% (dry matter); also nitrogen and copper content is higher than normal value.

Following it's possible having a comparison between chemical characteristics of vineyard pruning (test 1-4) and untreated wood.

Parameter	U.M.	Test 1	Test 2	Test 3	Untreated wood
Average water content (%)	%	13,04	11,05	12,24	20,8
Ash content (% t.q.)	% t.q.	4,11	3,24	3,15	-
Ash content (% dry)	% s.s	4,73	3,65	3,59	2,1
NCV (MJ/kg)	MJ/kg	15,9	15,9	16	
NCV dry (MJ/kg)	MJ/kg	19,91	19,57	19,95	18,7
Chlorine (% dry)	% s.s	0,02	0,02	0,01	0,1
Sulfur (% dry)	% s.s	0,02	0,02	0,02	0,1
Total nitrogen	% s.s	1,05	0,7	0,88	0,3
Arsenic	mg/kg	0,21	0,28	0,13	1,4
Lead	mg/kg	< 2	< 2	< 2	31,3
Cadmium	mg/kg	< 0,3	< 0,3	< 0,3	0,6
Mercury	mg/kg	< 0,1	< 0,1	< 0,1	0,1
Copper	mg/kg	44	30	31	22,3
Chrome	mg/kg	12	9	10	22,8
Zinc	mg/kg	39	45	43	52,5
Sodium	mg/kg	80	122	66	426,5

Table 25: Vineyard pruning analisys

FIGURE 108: Vineyard chips

9. *PELLETIZING OF VINEYARD PRUNING*

It's well established that vineyard pruning could be destined to pelletizing processes.

The main aim is obtaining a standard product to use in medium-small size plants and avoid problems related to combustion of irregular wood chips from vineyard pruning.

The main process applied to obtain pellet are the following:

- store for raw materials with a water content higher than 30%
- drier: the raw material is dried until a water content of 12%
- silo for the transfer of the dried material
- refiners to reduce the raw material into particles (a few millimeters)
- conditioning of the raw material: obtainment of natural binders ≤ 2%
- pelletizing of vineyard pruning
- cooling of the pellets. The finished product is then ready to be bagged or left in bulk for sale.

The following table describes the main parameters (range) that constitute process of vineyard pruning pelletizing.

Description	U.M.	Value
Average yield (vineyard pruning)	t/h	1,1-1,8
Collecting costs	€/t	22-35
Price of raw material	€/t (M 50)	30-45
	€/t (M 8,39)	50-84
Transport costs (M 8,39)	€/t	20
Pellet production costs (M 8,39)	€/t	154-187
Sale price (M 8,39)	€/t	180-200
NPV (15 year)	M €	2,35-10,47
Return time	y	3-6

TABLE 26: Vineyard pelletizing costs

With a pelletizing cost of 154-187 €/t and a sale price of 180-200 €/t (8,39% water content) it's possible obtain a unitary profit of 7-46 €/t, depending on collecting system adopted, transforming and producing technologies and market trends.

Those economic value permit to have 2,3-10,4 million euro of NPV in 15 years and a return time for investment around 3-6 years.

Chemical characteristics of vineyard pruning pellet

Pellet produced by vineyard pruning is characterized by an ash content higher than normal parameters imposed by Pellet gold certification (2,8 vs <1 – dry matter). Also nitrogen and copper content, as for wood chips, are higher than normal values.

Following it's possible having a comparison between chemical characteristics of pellet from vineyard pruning and conventional pellet gold parameters.

Parameter	U.M.	Vineyard Pellet	Pellet Gold
Average water content	%	8,39	< 10
Ash content	% t.q.	2,57	-
Ash content	% s.s	2,8	< 1
NCV	MJ/kg	16,5	> 16,9
NCV dry	MJ/kg	19,6	-
Chlorine	% s.s	0,02	< 0,03
Sulfur	% s.s	0,02	< 0,05
Total nitrogen	% s.s	0,39	< 0,3
Arsenic	mg/kg	0,09	< 0,8
Lead	mg/kg	1,8	< 10
Cadmium	mg/kg	< 0,1	< 0,5
Mercury	mg/kg	< 0,01	< 0,05
Copper	mg/kg	18	< 5
Chrome	mg/kg	1,7	< 8
Zinc	mg/kg	24,7	< 100
Sodium	mg/kg	60	< 300
Mechanical durability	%	98	> 97,7
Bulk density	kg/m³	627	> 600
Density	g/cm³	-	> 1,15

Formaldehyde	mg/100g	-	< 1

Table 27: Vineyard pellet analisys

10. *Results of combustion tests*

a) Wood chips

Fondazione Mach – SM Adige (2010) tested the combustion effects and pollutant emission of wood chips from vineyard pruning in 2 different type of plant:

- 1 domestic plant with 55 kW power
- 1 industrial plant with 8 MW power (2 boilers with 4 MW).

The results obtained from these tests are compared with limit emission imposed by National D.Lgs 152/06. Following are reported the results obtained during experimentation.

Figure 109: Vineyard chips

Thermal power	55 kW (domestic)		8 MW (industrial)	
Grate	mobile		mobile	
Feeding	auger		pusher	
Smoke treatment	--		ESP	
Management of burning param.	manual		automatic (fixed % O2)	
	55 kW		Combustion - 8 MW	
	Test 1	Test 2	Pruning wood	Chipped wood
Total dust	145,2	169	5,8	0,6
Total org. C	3,6	< 1	< 1	nd
CO	674,9	418,1	148,5	13,7
NO2	233,7	345,3	208,2	168,3
SO2	5,2	< 1	8,1	11,02
	National limits D.Lgs 152/06			
	35-150 kW	150 kW-3 MW	> 6 MW	
Total dust	200	100	30	
Total org. C	-	-	30	
CO	-	350	250	
NO2	-	500	400	
SO2	-	200	200	

Font: S. Silvestri e A. Cristoforetti (Fondazione Mach – SM Adige, 2011)

TABLE 28: Combustion test results

FIGURE 110: Residual of pruning combustion

Tests show that limits of combustion are well respected in both cases.

b) Pellet

Combustion of pellet from vineyard pruning causes some different emission values respect conventional pellet (woody pellet). In the following table it's possible observe the difference between two emission compositions, average produced in pellet plants. Tests was conducted by Austrian Bioenergy Centre (GbmH) with a boiler with following characteristics:

- combustion chamber with refractory covering
- power: 15 kW
- Combustion regulation: Lambda-probe
- other parameters: optimized for combustion

FIGURE 111: Vineyard pruning pellets

Emissioni		Vineyard pellet	Woody pellet
O2	%	10,2	5,3
CO2	%	10,2	15,1
CO	mg/Nm3	64	44
NO	mg/Nm3	203	-
NO2	mg/Nm3	3	-
NOx	mg/Nm3	206	132
SO2	mg/Nm3	12	nm

TABLE 29: Vineyard emissions comparation

NOx and CO emissions are higher with combustion of vineyard pellet than woody pellet.

However all emission caused by combustion of vineyard pellet are clearly under the parameters imposed by national and European limits for combustion emission (D.Lgs. 152/2006 and EN 303-5).

Following are reported tests for vineyard pellet combustion compared with limit imposed by legislation.

Description	kW	D.Lgs. 152/2006 35-150	EN 303-5 150-3000	Vineyard pellet < 50	50-150	150-300	1° test (25 kW)	2° test (15 kW)
Total dusti	mg/Nm3	200	100	150	150	150	108-131	41-54
CO		350	300	3000	2500	1200	380-640	64
NOx		500	500				190-204	206
SOx		200	200					12

Table 30: Vineyard pellet emissions comparation with legislation

Cristoforetti (2010) made a series of combustion tests with a small-size boiler (50 kW), where emission from different woody fuels, with and without filters in the flue of boiler, were examined.

Following are reported results of tests, expressed in mg/Nmc for total dust and total metals issued from boiler in different tests:

- Pruning OFF / ON (with and without filter)
- BIO
- Mix OFF / ON
- Wood chips OFF / ON
- Vineyard pellet OFF
- Wood pellet OFF

Results are compared with limit emission imposed by D.lgs 152/06.

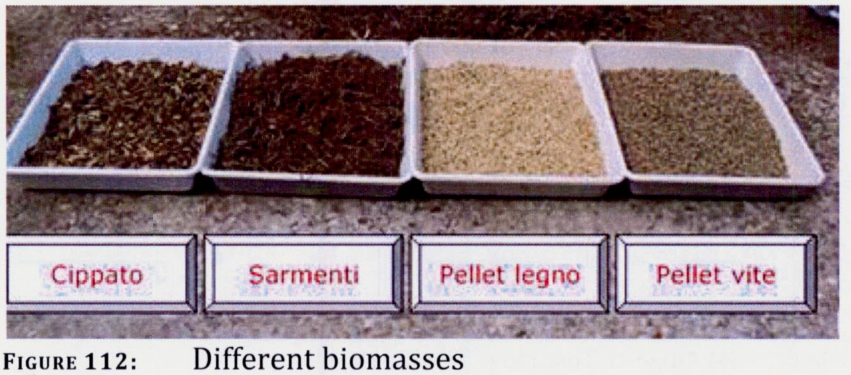


Figure 112: Different biomasses

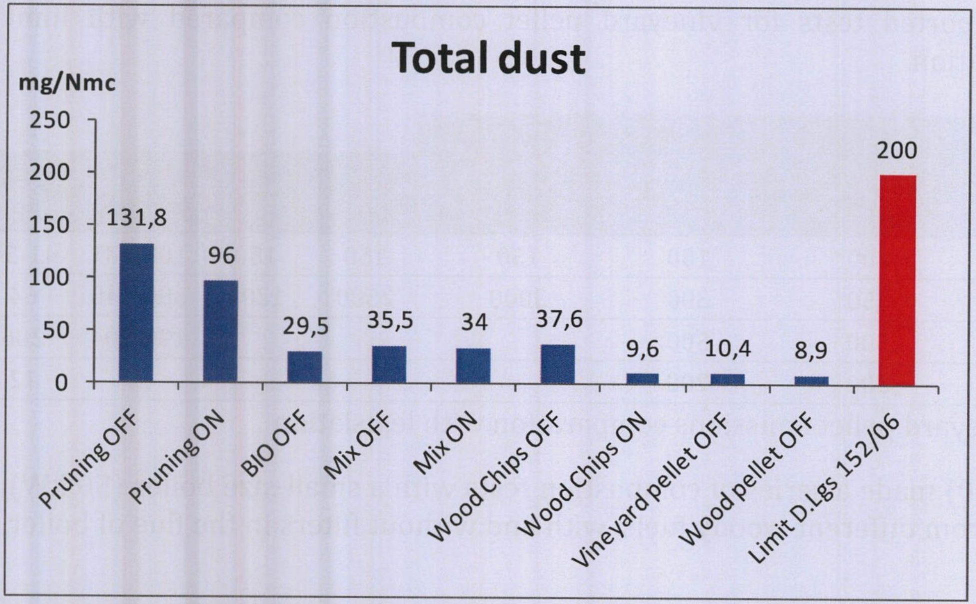
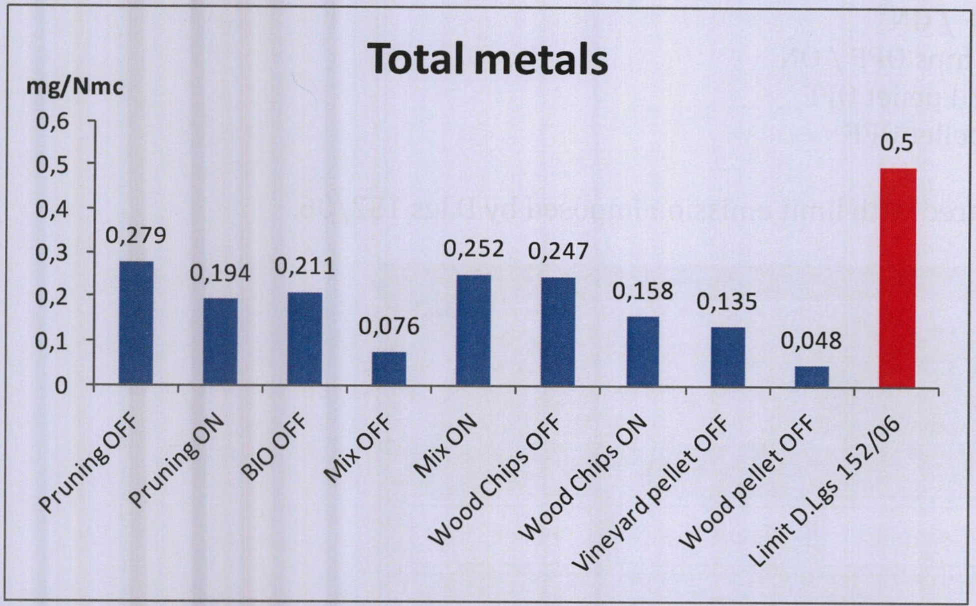


FIGURE 113: Total dust emissions from several biomasses

ON: with filter
OFF: without filter



Font: A. Cristoforetti (Fondazione Mach – SM Adige, G. Toscano (CTI) – 2010

FIGURE 114: Total metal emissions from several biomasses

Tests show that limits of combustion are well respected in all cases.

C. PLANTS DISTRIBUTION

Vineyard pruning could be used in different way, depending on geographic area. In north regions, particularly in Veneto where vineyards are more present, pruning could be used in thermal or in CHP plants. An high presence of plants in this area offers a wide choice for the final destination of the material. Attention should be given to the quality of the material and characteristics of energy plants, that must be able to use low-quality material.

Pruning obtained from vineyard in south regions, probably could be destined more easily to plants for combined heat and power generation or power generation.

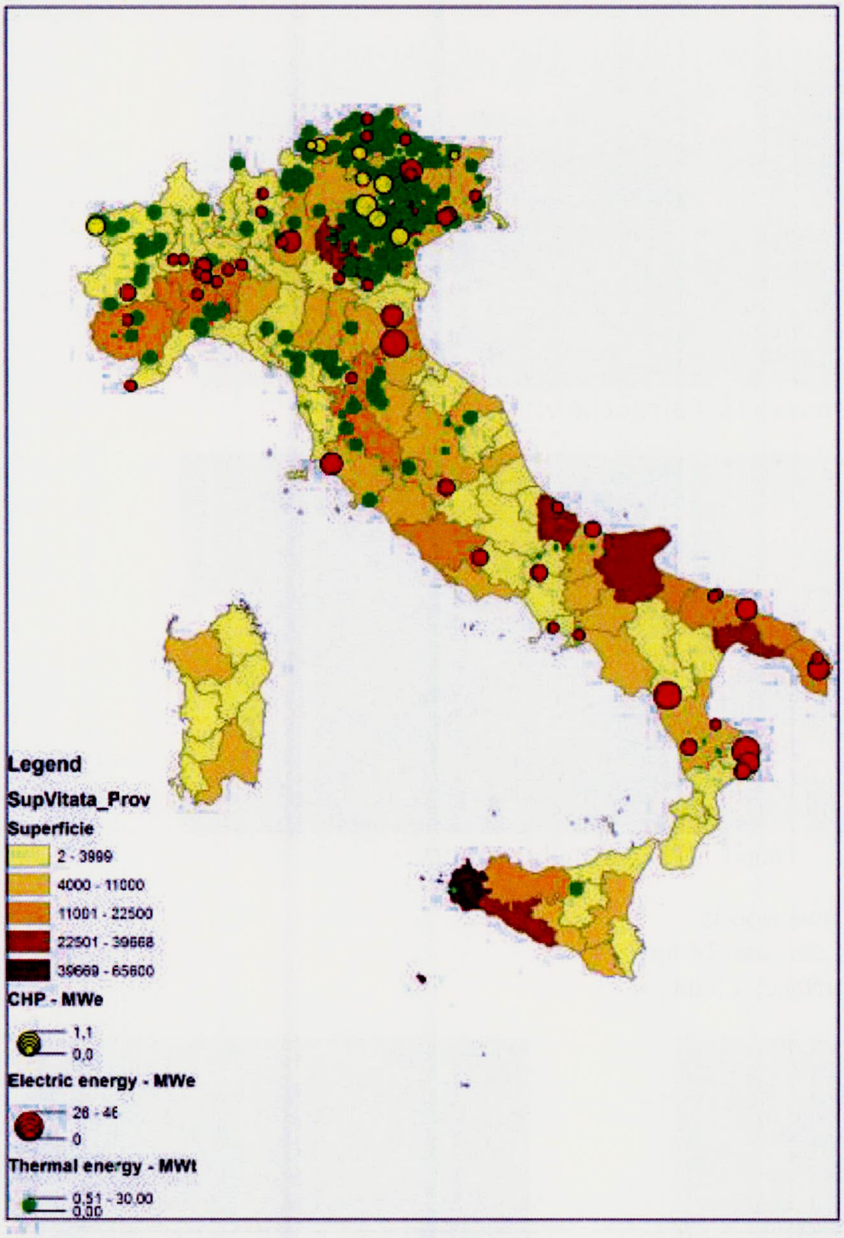


FIGURE 115: Woody biomass plants distribution and area covered by vineyard cultivation.

E. CALRONCHE - VINEYARD FARM WITH FARM-HOLIDAYS AND WINERY

www.calronche.it - Crevada di Refrontolo (TV)

FIGURE 116: Calronche vineyard farm

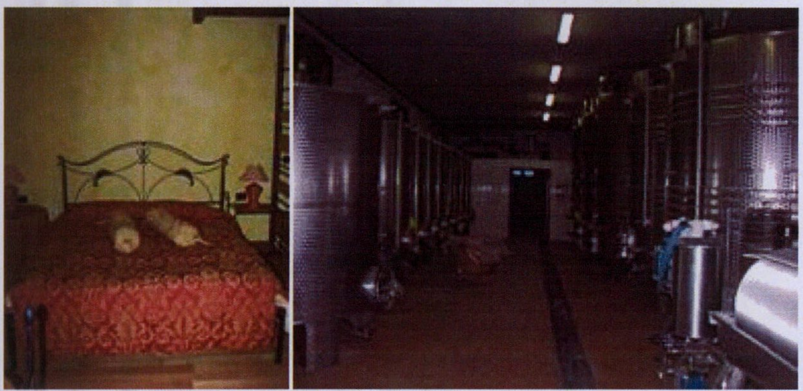


FIGURE 117: Calronche winery

cultivation of vineyard and woods

- vineyard surface: 14 ha
- woods surface: 4,5 ha

FIGURE 118: Chipper machines used in Calronche

- wood chips productions from farm:
  - yield of vineyard with auto-feeding chipper machine (Peruzzo): 20 t/year (M 20)
  - yield of woods: 15 t/year (M 45)

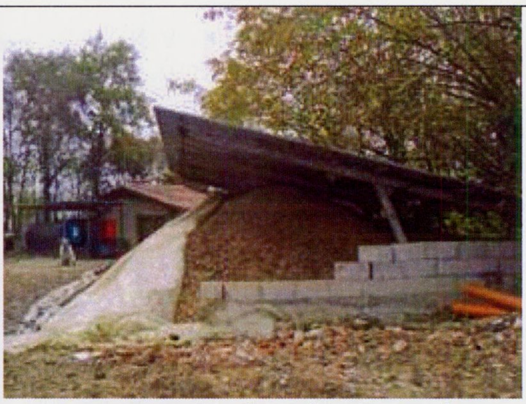


Figure 119: Stockyard in Caronche

boiler supplied with wood chips from vineyard pruning and wood chips from woods

- boiler characteristics:
  - heating power: 180 kW (with 3 heat exchangers – 25 kW)
  - length of district heating network: 100 m
  - dimension of storage silo: 5x5x3 (75 m^3)
  - puffer: 2.000 liter
- volume heated: 2.000 m^3 (+ 1.500 construction m^3)
- consumption July - December '09: 20 t (M 20)
- total investment: 150.000 € (45% of total funded by PSR)

Figure 120: Boiler and biomass feeding entrance in Caronche

Boiler instead:
- GPL boiler
- consumption: 2.000 m^3
- costs: 15.000 €/year

<u>INVESTMENT CONVENIENCE</u>

Investment: 150.000 € (contribution PSR 45%)
Previous cost (GPL): 15.000 €/year + boiler expansion = about 20.000 €/year
Wood chips auto-product: about 50 €/t (M30)
Consumption: 90 t/y = 200 MWh/y
Costs: 4.500 €/y
Saving costs: wood chips vs GPL about 15.000 €/a
Amortization: (150.000-67.500)/15.000 = 5,5 years return time
(building works duration: 100 years, district hating 50 years)

F. RUSALEN FRANCO - VINEYARD FARM

Motta di Livenza (TV)

FIGURE 121: RUSALEN Franco - Vineyard farm

farm with cultivation of vineyard

- vineyard surface: 10 ha

Figure 122: Baller and chipper machines used in RUSALEN Franco

- wood chips productions from farm. Rusalen opted for a preliminary packing of vineyard collected in field. Pruning bales are stocked and chipped in the farm after storage. Wood chips obtained is accumulated into storage silo.

- yield of vineyard with baling and chipper machine: 20 t/year (M 30)

boiler supplied with wood chips from vineyard pruning

- boiler characteristics:
    - heating power: 60 kW
    - puffer: 3.000 liter
- volume heated: 300 m³ + offices
- total investment: 50.000 € (55% of total funded by PSR)

Figure 123: Boiler in RUSALEN Franco

Boiler instead:
- Diesel oil boiler + Logs
- consumption: 1.000 l (diesel oil) + 30 t (logs)
- costs: 7.000 €/year

INVESTMENT CONVENIENCE

Investment: 50.000 € (contribution PSR 45%)
Previous cost (diesel oil + logs): 7.000 €/year
Wood chips auto-product: about 80 €/t (M30)
Consumption: 20 t/y
Costs: 1.600 €/y
Saving costs: wood chips vs diesel oil + logs: about 5.400 €/a
Amortization: (50.000-27.500)/5.400 = 4 years return time
(building works duration: 100 years, district hating 50 years)

EMINA Wineries

Valbuena de Duero (Valladolid)

Bodegas Emina is a company from the Ribera del Duero's region which is integrated within the Group Matarromera, with 100 permanent employees and 100 temporary, in 2005 it has installed a biomass boiler to heat its wine interpretation center.

The company is in a complex with 10,000 m2 of floor composed of the winery, conference hall, training room, laboratory, offices, museum, shop, distillery, among others.

The use of renewable energy together with other developments not directly related with energy such as cosmetics from grapes and wine, make Emina distinguish against other companies.

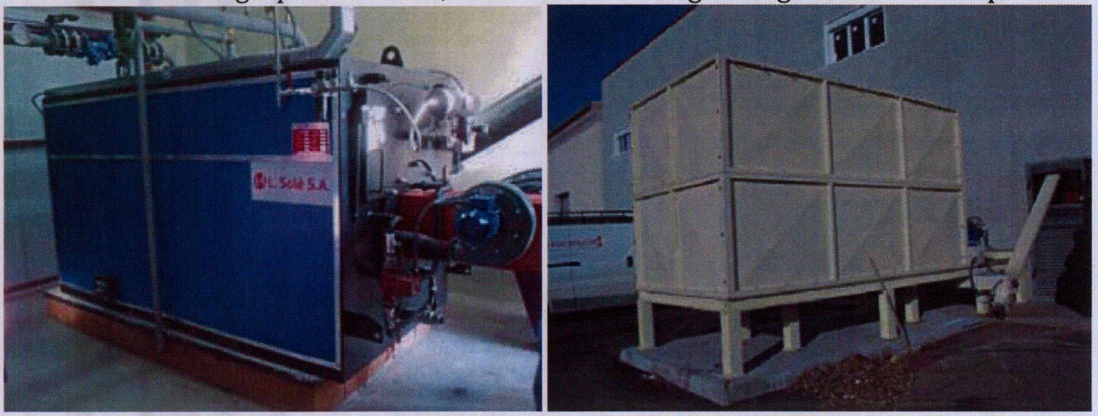


Figure 124: Boilers and biomass silo in Emina Winery

PROJECT DESCRIPTION:

Biomass supply: The biomass used has two sources: its own biomass, in the case of the vineyards prunings and the remains of grapes bunches and grapes (predominantly scrape), and biomass from outside, which is basically pinion husks from the vicinity.

Company technicians face with the dilemma of using its own waste, cheaper and easier, or purchasing biomass from other suppliers with higher quality.

In any case, to improve self-sufficiency, the company has built a crusher that reduces and homogenizes the size of the vineyard pruning.

Pinion husks and the vineyard pruning, have low humidity and good PCI, while the scrape and other residues from the winemaking are worse quality. The estimated production and consumption is 130 t / yr of biomass.

Boiler: The boiler is of 172,000 kcal / h (200 kW t). The feeding automatic, grate firing home, pirotubular system, cyclone fume scrubber and heat recovery. The heat transfer fluid is water at 90° C.

Also, it has been installed solar panels for hot water and a complementary gas boiler.

Distribution and consumption of thermal energy: thermal energy produced is used for the industrial process and for heating the building. Its operation is based on receiving a stream of hot water that is sent to all the destinations.

Investment:
The total ccst of the facility, including heat production and distribution, has been of 130,000 €, receiving a grant of 51,000 € from a saving, substitution, cogeneration and renewable energy program frcm the Junta de Castilla y Leon.

RESULTS:

Energy: Use of biomass avoids the dependence on external energy sources. Energy diversification is estimated at 49 toe / year.

Technology: The incorporation of modern biomass systems and automated is now an innovative and distinctive in the vineyard and wine industry.

Environmental: Reduces emissions and adequately self-manage their own waste.

Economic: The cost of thermal energy is reduced.

XI. DRYING OF WOOD-FOREST CHIPS

Prepared by: Mireia Codina and Ignacio López (CTFC)

A. INTRODUCTION

Biomass in general and primary forest biomass in particular are getting more importance as a renewable energy source which will be of common and sustainable use in the future due to the increment of atmospheric CO2 from the use of fossil fuels for a long period, causing a global warming, and also due to the future depletion of such fuels. In addition, the use of renewable biofuels will play an important role in terms of carbon emissions trading.
Primary forest biomass for energy is that one coming from silvicultural treatments, thinnings, clearings, forest fire prevention works and also from commercial cuttings.
The features of this material are mainly its heterogeneity and it dispersion on the land, and it high moisture content in fresh material. Due to this moisture it is necessary to, prior to burn, remove the excess water for a better combustion.
The aim of storage a drying is to obtain a high-grade solid biofuel, namely with a low moisture content and therefore a high calorific value and a low ash content.
The quality of forest chips is dependent upon the source of the biomass and the techniques employed for comminution, handling and storage. Consistent particle size, low contents of moisture and foliage, and low ash production improve the useability of the plant and efficiency and economy of combustion.

The most important single quality factor is the moisture content of chips. Moisture content is a direct cost factor, and it is taken into account in the pricing of the fuel. An excessive moisture content results in a price reduction, while a low moisture content brings a bonus. It affects the heating value, storage properties and transport costs of the fuel [9]:

- Effective heating value. Vaporization consumes 0.7 kWh heat energy per a kilogram of water. If the moisture content of fresh softwood is reduced from 55% to 40%, the initial amount of water is reduced by half, and the effective heating value increases 8%.
- Efficiency of combustion. Moist wood tends to combust incompletely, and a part of the heat energy of the fuel is then lost. This is a problem particularly in small boilers where the temperature remains too low if the fuel is moist.
- Emissions. Incomplete combustion results in increased emissions of carbon monoxide, hydrocarbons and fine particles.
- Storage properties. Chemical and biochemical reactions take place during the storage of chips, particularly if the biomass contains active nutrient-rich material such as foliage. Dry matter loss can be avoided only when the moisture content is less than 25%.
- Handling problems. In winter, moist chips may freeze in a truck load or silo causing blockages and damage to the fuel handling system of a plant.

Different boilers demand different fuel properties. In small-scale boilers, the total efficiency of the boiler decreases rapidly when the moisture content rises (boiler tests are usually made with fuel that contains 30% or less moisture), because the moisture content decreases conversion efficiency into energy and increases gaseous emissions (incomplete combustion). So, when using dry fuels the boiler stays cleaner, and malfunctions and need for maintenance decreases.
The larger the plant, the more tolerant it usually is of random variations in fuel properties. Even so, knowledge of fuel properties and careful control of quality are essential to the operational reliability and efficient combustion of all boiler systems.
In natural drying the moisture content is decreased without the need of external input of energy different from the ambient conditions (solar radiation and wind). However, with natural drying, wood will never reach values under those corresponding to the equilibrium to ambient. This is

why sometimes it will be necessary a technical drying with addition of heat and with forced ventilation.

B. WATER IN WOOD

Trees take up water from the soil for photosynthesis and to transport nutrients to the growing parts of the tree. The water transport activity is focused mainly in the sapwood, so that the cells that constitute it are saturated with water in order to allow that exist uninterrupted water columns from the roots to the leaves. Thus, green wood contains water in three forms:

1. Free or imbibition water: the bulk of water contained in the cell lumina is only held by capillary forces, it is not bound chemically. Is located in the macro pores, cavities of the conductive vessels and parenchymal cells.
2. Bound or saturation water: is bound to the wood via hydrogen bonds. Is located in the micro pores (mainly cellulose, hemicellulose and lignin).
3. Vapor: water in cell lumina in the form of water vapour is normally negligible at normal temperature and humidity.

Wood begins to lose water from the moment the tree is cut down. First, free water evaporates from the largest-sized capillaries (sapwood). When all this water is evaporated, the bound water reaches a dynamic balance with the outward moisture, called fibre saturation point (FSP), reaching an average value of 30% (dry basis; or 23.1% on wet basis[2]).
From the FSP, *wood can only increase its water content if it is supplied by rain or immersion*. On the other hand, under the FSP, the absorption and transfer of water is performed by gas exchange with the atmosphere. These processes are called adsorption and desorption, and result in dimensional variations in the wood.
When dry or green wood is exposed to atmospheric conditions, it gains or loses moisture to reach equilibrium with the atmosphere. This equilibrium is called equilibrium moisture content (EMC) and is always less or equal to the FSP.
The EMC of wood varies with the ambient relative humidity significantly, and to a lesser degree with the temperature. EMC also varies very slightly with species, mechanical stress, drying history of wood, density, extractives content and the direction of sorption in which the moisture change takes place (i.e. adsorption or desorption).

C. NATURAL DRYING

Woody biomass can be stored in the form of chips, chunks, billets or uncomminuted. Various storage forms and seasonal changes have effect on wood fuel quality.
The length of time biomass should remain in storage is a critical factor to be considered, since storage influences not only changes in physical and chemical properties of biomass but also operating costs to be met by the biomass power plant.

1. ENVIRONMENTAL CONDITIONS

The more important conditions for drying are function of:

- relative humidity of the air
- initial moisture content of wood
- dimensions of the wood/chip (and bark thickness)
- exposure to wind
- orientation of the field where it is stored

[2] Value accepted in general terms for wood. Differences between species exist and may be significant. For instance in a compilation made of several values for Basque wood, for *Pinus pinaster* it is 32,3% (db) and for *Castanea sativa* 28% (db) [29].

Relative humidity is the most important factor among those affecting moisture content in wood [1]. Depending on the environmental conditions of temperature and humidity, wood will lose some of the bound water to a point of equilibrium (EMC).
For instance in Catalonia, according to the altitude there are differences in the drying rate of wood. Thus, in areas below 1,000 m the drying rate is higher between May and September, while in areas over 1,000 m this threshold is lower from June to mid August. During these months is when the vapour pressure deficit is higher and the tree can quickly lose moisture through their foliage or bare wood surface. As relative humidity increases, moisture loss is reduced both by decreasing the vapour pressure as the hygroscopicity of wood. By contrast, in Finland the best season for drying is May through August.
Moisture content of fresh woody material, just harvested or not too much after harvesting, shows differences among species and also among seasons. In general there is more water in wood in spring and summertime and in any season when the trees are growing (40 - 60% wb), and less in winter and in dry summers, but for some Nordic species there is more water during winter.
Some studies have found that the material seasoned for a long time can keep low moisture contents. So, although from the logistic point of view seasoning is a bottleneck process, it has clear advantages from the point of view of quality.
Well orienting the piles of roundwood or residues in order to take the best profit of winds is a good recommendation. In that way, piles should be built perpendicular to dominant winds in order to maximize the esposed area and the evacuation of water vapour.

a) Desirable features of the storage yard

When designing a storage yard for low-quality roundwood or forest residues, in order to be operative and effective in the distribution of processes of the biofuel preparation, the following characteristics are desirable:

- Flat areas without vegetation
- Good accessibility for vehicles to enter and exit the area (road or concreted road)
- Availability of a weighting scale, or at least in the vicinity
- Far enough from wooden lands
- Near watering points, in order to extinguish fires if they occur
- Good exposure to sun and wind
- Well drainage capacity of the ground, in order to avoid rewatering of wood from the ground

The storage yard must have a perimeter strip road of 5-6 meters width. Depending on the dimensions of the yard, there must be also one or several streets crossing the yard, with the same width, in order to allow manoeuvrability of machinery.

b) Uncomminuted fuelwood

This process is commonly called *seasoning* and is well known in nordic countries where logging residues are systematically seasoned for, at least, one year prior to chipping. This process is unnecessary, when the comminuted material is to be burned in large moving grates, where fresh material is accepted. When conditions are favourable, any uncomminuted fuelwood (e.g., whole trees, whole stems, split firewood or logging residue) that is stored fresh on a roadside landing or a terminal is likely to loose moisture over time.

c) Storage time and moisture control

As it has been stated in diverse studies, seasoning roundwood of low quality permits having a very dry material after few months. For example, in the study carried out by Kent and Kofman in 2007-2008 ([16] and [17]) with delimbed pulpwood and crudely delimbed energy wood, it was found that stacks of roundwood can lower their moisture content from around 60% (wb) to 30% in 14 weeks when stored at mid spring (April) and 26 weeks when stored in early winter (December), staying will low moisture of round 21% (wb) for a long time.
A similar study performed in 2009-2010 in Austria by Kanzian (personal communication and [15]) shows somehow different results, where small softwood (average 15.2 cm over bark) seasoned from December 2009 to January 2011 had only reached a minimum 31,1% moisture (wet basis) after summer 2010; wood with this moisture is anyway in conditions to be comminuted and burnt in almost any furnace. From the point of view of logistics, this is a crucial issue that must be taken into account when sizing storage areas,
If the moisture content of the raw material is not estimated with models, direct measurements may be done. Similar methodologies to those for firewood could be followed (figure 0), where diverse protocols of measurement have been done by the TFZ in southern Germany [24] using moisture meters as the one shown in the photograph 0.

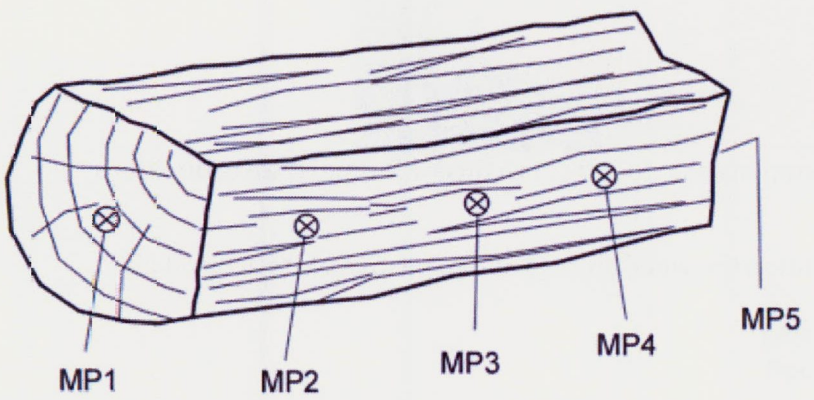


FIGURE 125: Measuring points tested by TFZ. Source [24]

FIGURE 126: Moisture meter for solid wood, measuring a radial freshly cut section

A destructive method has been also tested by CTFC in collaboration with the University of Agrarian Sciences of Vienna (BOKU) consists on sampling the shavings from a chainsaw (photograph 0), well sharpened and with selected sections. Preliminary results by CTFC show an underestimation of 3 percentage units of moisture content (wet basis) due to friction when cutting the log.

FIGURE 127: Example of sampling shavings from chainsaw for moisture estimations

The main factors which condition the wood storage and to be taken into account are:

- Ambient conditions
- Phitosanitary conditions
- Drying capacity of wood
- Space requirements

2. *PHITOSANITARY CONDITIONS*

The most important changes in wood have a biotic origin, meaning that they are produced by living organisms.
Fungi grow in wood when it presents, simultaneously, the following characteristics [28] and [14]:
Moist wood: the development of fungi is faster when the wood moisture ranges between 30% and 60% (wet basis), value which is the most common for wood when is placed in storage yards after harvesting (figure 0)

- Temperature: the range of temperature optimum for fungi development is 20-35ºC (figure 0)

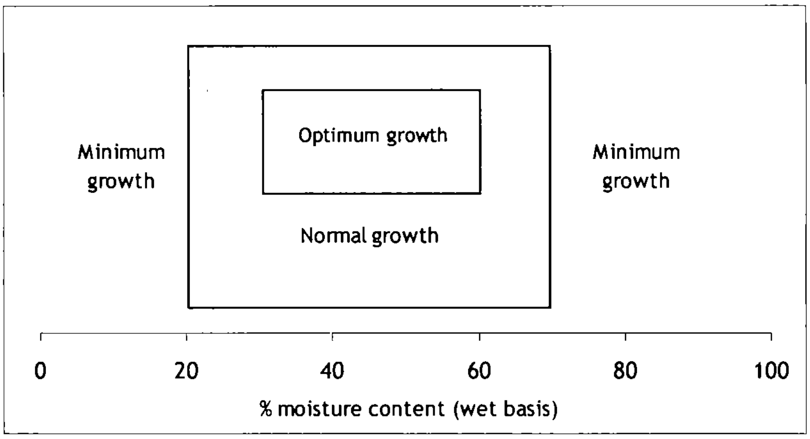


FIGURE 128: Moisture conditions of wood for the growth of fungi. Source [14]

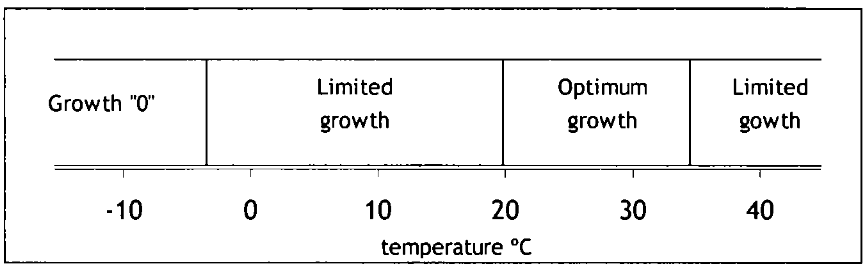


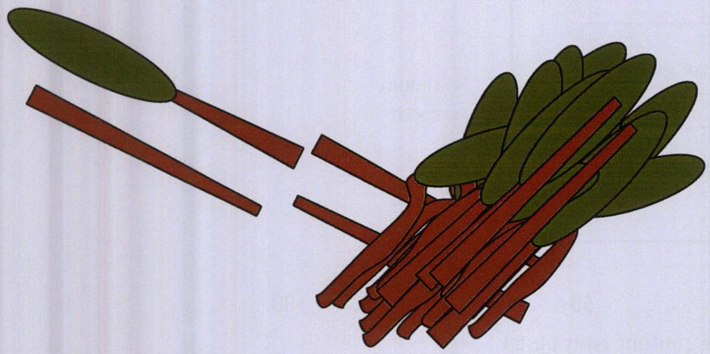
FIGURE 129: Temperature conditions for the growth of fungi in wood. Source [14]

The most important pest insects that can attack weakened or piled wood are wood engravers (*Tomicus* and *Ips*) and, once their presence is detected in wood piles, these should be immediately comminuted. The importance of controlling the presence of this kind of insects is based on the possibility that raw-material piles constitute a focus for the dissemination of an insect pest. In general, raw material piles should not stay in forest areas longer than two weeks. It is possible to leave wood piles longer in forest areas if the legislation in force allows it and the life-cycle of the pest insect does not suppose any risk during the storing time. In that sense, it must be taken into account that in some Mediterranean countries with mild climate even in winter, insects may remain active in this season.

a) Characteristics of the piles of logging residues

The moisture content of logging residues will decrease rapidly if they are left in small heaps during the summer. However, with the risk of re-wetting in cases of wet weather, the method in which the residues are forwarded into a windrow directly after felling and immediately covered with impregnated paper may offer a better alternative [12].
So, starting in September until May, the piles of tree-tops and logging residues can be covered with a protective paper (for example, Walki®Biomass Cover 246 g/m^2) for prevent rain and snow to moistening the piles. It has been indeed proved that covering the piles of logging residues, even in locations with high precipitation, gives a better quality fuel than storage of chips with respect to homogeneity in moisture content of the fuel. ([11], [12] and [18]).
One of the most important advantages of covering the piles is the associated energy efficiency. When a pile is covered, wood can naturally dry and hence its energy content increases significantly. The piles are not covered by their sides, so that the air can circulate within and intensify the drying processes. The benefits from covering the piles are greater when the snow is melting, in spring, because in that wood does not absorb this melted water.
A common method to avoid contamination of wood in piles of raw material, as well as to prevent the wood of being in contact with the ground and get water from it, is shown in figure 0 and

photograph 0. This is meaning losing the logs cross-located in the ground to form the



"platform".

Figure 130: Forming a pile of small diameter stems and whole trees, where the stems in contact to the ground are placed perpendicular in order to form a platform

Figure 131: A small pile of energy wood of Castanea sativa piled to avoid contact to soil

Storing raw material in yards or at landing will be done in the same way wood industries do it, forming piles as high as possible, in a way that the use of the available space is maximized and the protective paper (if used) is covering as much wood as possible. In contrast to wood industries[3], any mean or layout to accelerate natural drying processes is prioritised.
The conditions under raw material looses water have been exposed before, and therefore there are important differences between:

- short roundwood (CTL wood) of low quality
- whole trees from thinnings
- logging residues

In any of these cases, experience gained by entrepreneurs show that any material should be seasoned round one year (minimum 6 to 10 months) in order to reach a moisture content of 30% (wb).

[3] Wood industries prevent wood to be too dry in order to avoid splittings and a too hard material for the saws

D. COMMINUTED FUELWOOD

The main factors which condition natural drying processes of comminuted material and to be taken into account are:

- Phitosanitary conditions
- Thermogenesis process
- Ambient conditions

1. *PHITOSANITARY CONDITIONS*

In wood-chip piles there are mainly four types of fungi present:

- Moulds (Aspergillus, Penicillum, etc): they degrade substances of the surface of the particles, but not any component of the cell-wall. The losses they originate are insignificant, but these may cause problems in people with sensitivity to them
- Rot moulds (ascomicetes and deuteromicetes): they degrade mainly the cellulose of the cell-wall
- Brown rot fungi (basidiomicetes): they are responsible of the degradation of the cellulose of the cell-wall
- White rot or fibre rot (basidiomicetes): they are responsible of the degradation of the lignin of the cell-wall

The types of fungi present depend on the type of material, the particle size and the pile size. Rot fungi grow optimally at temperatures between 25 and 35 ºC. Their metabolism is much lesser over 50ºC. Regarding moisture, under 16% wet basis (20% dry basis) fungal activity is minimal. In addition, under the fibre saturation point of wood, water present in wood is not easily available for fungi. By contrary, an excess of moisture also decreases the activity of fungi due to a lack of available oxygen for respiration.
Fungal activity is partly responsible of the increase of temperature until about 60ºC; initial increase uses to be due to the metabolism of living parenchyma cells. Over 40ºC this respirations is of less importance, but then fungi and bacteria are responsible of the steady increase of temperature until 60ºC (fungi) and 70ºC (bacteria).

2. *THERMOGENESIS PROCESS*

Inside wood-chip piles take place a set of physical (compaction), chemical (oxidation) and biological (fermentation, rotting) processes which mean an increase of temperature [19], variations in moisture content and a loss of dry matter; this is causing small convective flows of air within the pile, in a way that air enters the piles from the sides and exits in the top of the pile (chimney effect, see photograph 0), which accumulates an important amount of water consequence of this process. This convection takes place when the inner temperature of the pile is 5-10 ºC over room/outdoor temperature [14].

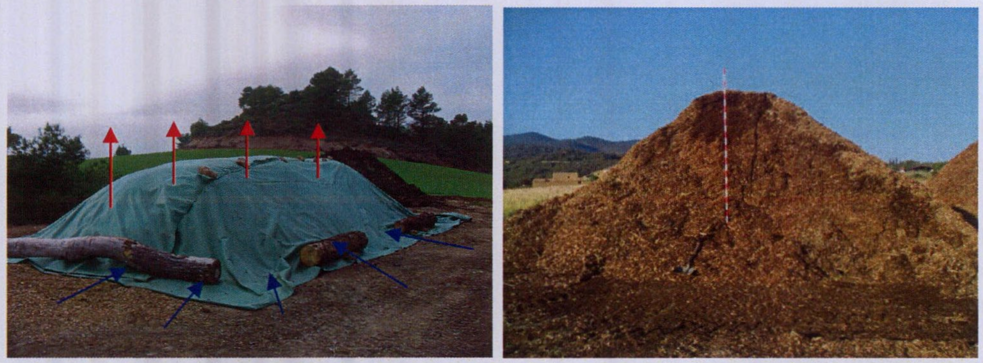


Figure 132: Thermogenesis process. In the second photograph it can be observed a 5-meter pile after 3 months of storage, with the top of with darker colour meaning a higher moisture content, and the right side with a lighter colour, meaning a very dry layer of wood chips. The rest of the pile had a moisture content of about 30% wet basis or fewer.

There are many factors which may influence on the self heating process in wood-chip piles, according to own gained experience and [8]:

- moisture content over 30% (wet basis) and moisture distribution when the pile is made
- tree species
- high foliage/needle content and bark and proportions
- particle size distribution of the batch
- shape of the pile
- environmental conditions
- storing season
- freshness of the wood
- cover type (if present; textile or built facility mainly)
- size of the pile (width and height)
- compaction degree (bulk density)
- management of the piles, in case they are moved, mixed, ventilated, etc.

Self heating of piles may help very effectively due to the convection flows created within the piles, but this may lead to a somewhat risk of self-ignition.
Risk of self ignition is related, according to [8], both to the heat production in the material and to the transport of heat, moisture and oxygen in the pile. The reasons for self-ignition have to be found in the exothermic reactions like slow oxidations, possible physical influences like coupled effects of condensation and wetting (mainly adsorption) of water molecules and microbial processes, which are occurring in large wood heaps at common ambient temperatures. Due to the poor heat conductive properties of the bulk material, the heat produced inside the pile could not dissipate to the surroundings completely. Thus, a positive heat feedback loop would be initiated, which would finally turn in an extensive fire [5].
[8] reports that most of these fires have started in the border zone between compacted and uncompacted material, or between materials with different particle sizes and/or moisture contents. In a study carried on in Sweden by Hogland et al. [10] with a pile of 3,5-4 meters high of 135 tonnes of solid residues including wood, the pile caught fire because of the presence of uncompacted areas which permitted the flow of oxygen; pyrolysis processes started, though, early after the pile was formed.
Pyrolysis process takes place from temperatures of about 200-250 ºC. If a chip pile reaches a temperature like that, its motion may lead to an open fire due to the availability of oxygen for combustion. Small piles (less than 5 m high and elongated) use to reach temperatures under 90-100 ºC (normally 60-80ºC), even when formed with chips from whole trees, the first 2-4 weeks after the pile formation. In case a pile catches fire [8] recommends:

- cut fire gaps around the heart of the fire
- remove as much undamaged material as possible

In order to minimize the risk, [3] recommends to:

- form different piles for different materials
- form the piles with the minimum possible moisture content
- avoid comminuting with blunt tools
- piles to be formed with coarse wood chips
- avoid important proportions of needles or leaves as well as easily degradable substances
- short storing periods
- good circulation of air (evacuation of heat and moisture)
- heights of the piles under 4 m, preferably without top flat areas (with linear shape)
- if needed, use technical drying or ventilation
- use probes to control temperature evolution

Under optimum conditions for the growth of fungi and bacteria (e.g., at moisture content of 40%), the heating is carried out after a few days (figure 0). On the contrary, microorganisms are not activated under conditions of permanent low temperatures (winter), unless they have previously been activated [14].

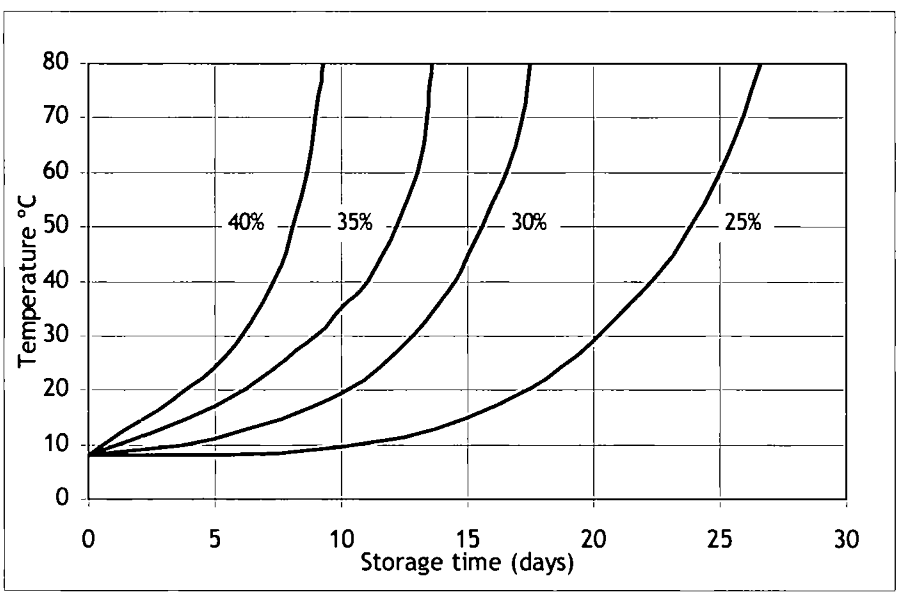


FIGURE 133: Heat development in wood chip piles the first days according to initial moisture content. Source [14]

Figure 0 shows the temperature evolution within three points of a pile of G50-type wood chips, made with roundwood and whole trees from sanitary fellings (codes 1.1.3.2 and 1.1.1.2 according to table 1 of the standard EN-14961-1). The values shown are 12-hour averages [4].

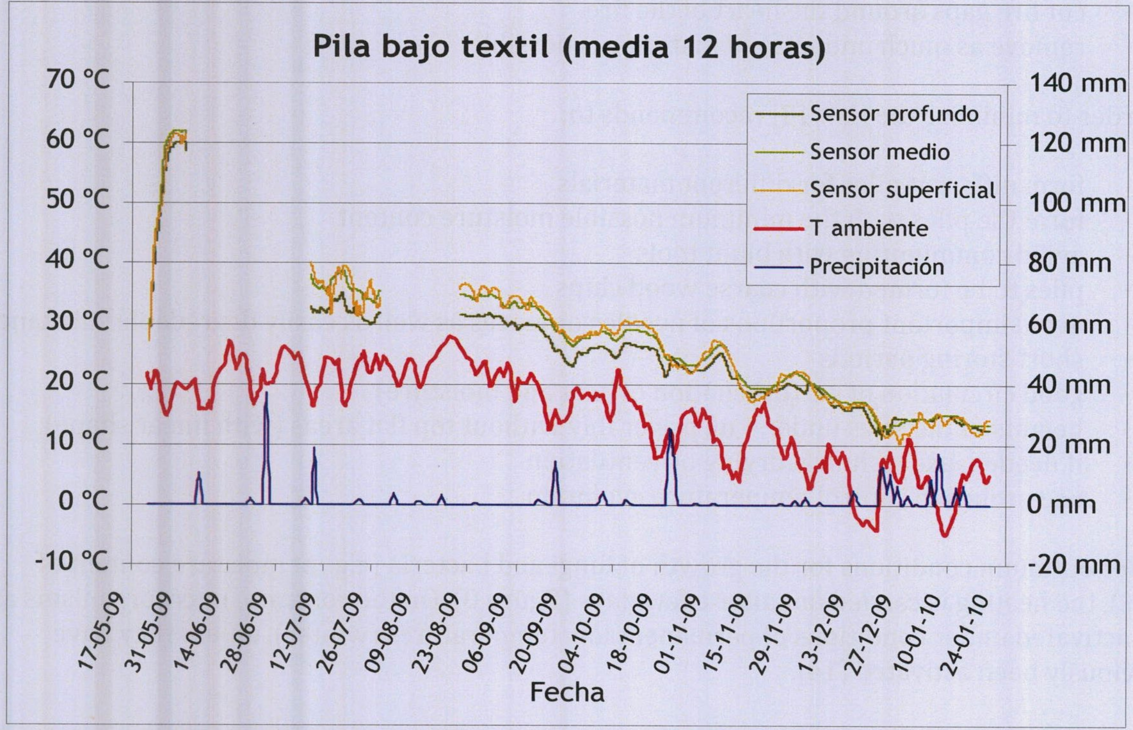


Figure 134: Temperature development inside a wood chip pile a three heights: dark green – 0,5 m from the ground, light green – mid height, yellow – 0,5 m from the top; red - environment temperature, blue - rainfall

An experiment carried out by CTFC in 2009 [4] in central Catalonia with small piles of 3 meters height, it was found that in the three months of summer moisture content dropped from the initial value of 42,4% (wet basis) to around 30% in the centre of the pile (see figure 0).

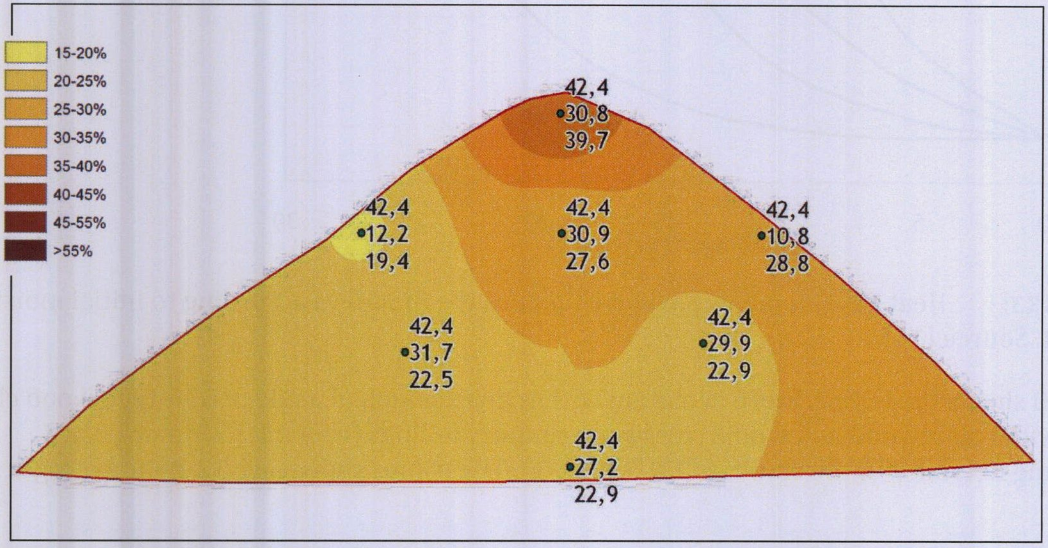


Figure 135: DW profile of the moisture of a wood chip pile stored under a textile at the end of the experiment. The values shown are the moisture content (wet basis) in the beginning (May 2009 - top), in the middle (august 2009 – middle) and in the end of the experiment (January 2010 – bottom).

a) Loss of dry matter

Dry matter ash free releases energy in the combustion process and it is therefore important to minimize its losses during storage.

The loss of volatile substances, respiration of living cells and the metabolic rate of microbes lead into dry matter loss and, therefore, a change in fuel quality. This variation in quality implies a reduction of the energy content of the material, with less carbon content, more lignin content (assuming that the main fungi cause brown rot) and more ash content.The loss of dry material in wood chip piles is greater as:

- the storing time increases
- the initial moisture content of the wood is higher (fresh biomass). Storing drier chips may suppose a dry matter loss of only 2% in 7-9 months in comparison to fresh, which could reach 20-23% dry matter loss.
- the green content[4] is higher
- the fines content is higher[5]

Weight loss during storage increased in the order:

- clean, debarked chips
- whole-tree chips
- bark
- foliage[6]

Losses in general can reach 10-30% per year, and in the parts of the piles where the biological activity is intense, losses can reach 40%. Covering the piles leads to somewhat lower losses.
In order to minimize such losses, biological activity must be kept as much as possible under control. Below is a list of measures to take, particularly for wood chips and bark which, among fuels, are most frequently affected by such problems [6]:

- Store material with the least possible moisture and keep it out of the rain;
- Favour natural ventilation: it quickens the loss of heat and water;
- Remember that a rough and regular size of the material encourages internal ventilation;
- Use adequately sharp cutting tools (regular size);
- Reduce to a minimum the presence of needles and leaves, which are easily attacked by microorganisms;
- Minimize the duration of storage;
- Choose an ideal height for the pile

3. *COVER TYPES*

a) Uncovered pile

Having the chips as they fall from the chipper or forming piles with front-end loaders or similar equipment is the cheapest and simplest way to store them. This may only have sense, though, in the following circumstances:

- only temporarily due to the use of a "hot system" when producing and evacuating wood chips

[4] Green content: ratio of the amount of needles and leaves in the fuel and the total weight as received (COST FP0902 glossary - 2011 not published)

[5] In that sense, storing hog fuel or coarse chips is more effective in terms of dry matter loss and natural drying, because circulation of air is greatly facilitated

[6] Foliage losses can roughly be ten times as high as those for clean, debarked chips

- only when ambient conditions facilitate natural drying processes, as far as the type of chips allow these processes (coarse chips, summer, dry days)

A pile stored uncovered is characterized by on the outer part it forms a thin layer of dry material (approximately 3 cm), approximately 20-25 cm of moist material and a part inside that is dry evenly [22].
It is important to consider the nature of the ground where the pile is to be formed. If the ground is natural, especial care must be observed in order to avoid the incorporation of impurities, namely sand (soil) and stones. In order to avoid these impurities, it is advised to leave a small layer 10-20 cm of comminuted material on the ground and load and use the chips over this height. In addition, wood chips in contact to natural soil trend to be moist.

b) Covered with fleeces

The fleeces commonly used for covering wood chip piles are made of fibres of polypropylene, very resistant to degradation (UV resistant) and relatively easy to handle. The material keeps its resistance 3-5 years, when it starts to get broken at small tensions. The textiles are used for their properties of being permeable to water, letting water from inside the piles to pass through it. In addition, the structure of fibres makes the rainfall to be evacuated through the textile down to the sides of the piles. There are at least two types of textiles which have been designed and advertised for covering comminuted wood (TopTex and Lest'o, see photograph 0).

FIGURE 136: Detail of two textiles. Left: TopTex. Right: Lest'o.

According to conclusions of Pari in 2008 after an experiment with piles of material from short rotation coppice in Italy [22], in covered piles, it is formed an outer layer of about 2 cm, rich on fungi and dry; the rest of the pile is dry evenly. So, this covering prevents the formation of a moist layer on the external part of the pile and seems to have a positive effect on the final quality of the material.
The main advantages of the use of textiles is the lower initial investment compared to that needed to build a structure, and the fact that wood chip piles can be covered with these fleeces almost everywhere. By contrary, it is needed certain care when placing the textile, and folds as shown in photograph 0 should be avoided, because these are hence places where rainfall can enter within the pile. The textile is not effective if placed forming a horizontal surface over a wide pile.

FIGURE 137: Folds to avoid

FIGURE 138: Example of good practices when covering wood chip piles provided by the forest state company of Bavaria (Bayerische Staatforsten). The arrow indicates the wind direction.

Covering wood chip piles with fleeces is to be recommended under these conditions:

- absence of any kind of building where to place the piles in
- forecast of rainy periods (its use permits to diminish the effect of rainfall obtaining a higher proportion of dry chips, compared to uncovered piles)

c) Buildings

When buildings are well designed, natural drying is better. Some important issues to consider when designing such a building are ventilation, isolation and accessibility.
The most important advantages of building such facilities are:

- increased capacity per area of storage (if there are walls)
- effective protection against rainfall
- depending on how it is built, it prevents contamination from sand and other impurities transported by wind

The main handicap of this storage is the initial investment (around 250-300 €/m²) and the fact that a failure in choosing the site it is crucial, by contrast to the flexibility provided by the textile. Small entrepreneurs are normally able to find an existing building where to start this activity.

FIGURE 139: Storage building in Mosset, southern France

4. ARRANGEMENT OF THE PILES

a) Induced ventilation system

The use of tubes for ventilation of the inner parts of piles is common in practice although some studies and practical experience seem also to suggest that no extra oxygen should be provided to fungi for better degradation (composting). In an experiment conducted by Pari in 2007 [23] moisture losses were found only on nearby areas of ventilation conduits, whereas the rest of the mass was not suitable for energetic conversion as the moisture values were too high at the end of the stocking period.

In an experiment by Jirjis in 1995 [12], ventilation of wood chip piles reduces the risk of self-ignition because the temperature of the pile is kept low. Within the same report it is stated that the moisture content of the pile, starting from a low initial value of 22% (wet basis), remained very low thanks to ventilation (15%) but although this, the fungal activity remained high due to good temperature for their activity.

Drying and/or cooling wood chip piles by ventilation is a possible system to improve fuel quality. However, two main points have to be considered in such a system; first the material has to be thoroughly and continuously cooled to temperatures below 15ºC to ensure minimal microbial activity, and second the sensitivity of the system to the price of the fuel[12].

b) Compression

The piles are pressed with a rubber-tyred tractor so to reduce the quantity of oxygen inside the pile. *This is a practice to avoid.*

FIGURE 140: A loader-excavator working on a pile of wood chips. A process to avoid whenever possible by using a telescopic loader

The behaviour of the compressed pile seems to favour keeping high temperatures inside the pile, especially on the higher part, which is the moistest part. So, compacting materials makes a product that is mostly useless or better still, moisture increases [23].
Compression has been shown to prevent efficient natural drying of wood chip piles, as it is also stated in the instructions of the forest state company of Bavaria (*Bayerische Staatforst*, [2]). Machines should avoid circulating over chip piles, and therefore big chip piles should be formed with telescopic loaders or stackers.

c) Shallowing

Wood chips are extended on an even and concrete layer for a fast removal of moisture. Obviously, days with a low relative air pressure and sufficient temperature are to be chosen for this process.

FIGURE 141: Wood chips extended on a concrete surface for accelerating moisture loss during a summer day in Central Catalonia

This is a good option provided the trade centre has enough surface and good climatic conditions, but is sub-optimal regarding costs, management intensity and logistics. Adapting logistics with a systematic use of this process may be complex, and may lead to forming piles of wet material waiting to be extended in which intensive decomposition processes may take place. The system is hot (cf. cold systems[7]) and with a somewhat risk of rehydratation of the whole batch.
This practice has been also tested in Nordic countries in the 1980s with the addition of ventilating devices [8].

d) Mixing

As commented before, this process is common in composting processes where even specific machines have been developed for this purpose. This action may improve the availability of oxygen for decomposing microorganisms, although the common sense makes think that better evaporating conditions are provided for wet wood chips.

5. *DRYING BEHAVIOUR ACCORDING TO PARTICLE SIZE*

Different drying behaviours may be observed between these **materials**:

- Chips (particle size of a few mm)
- Chunks (particle size up to 25 cm)
- Whole stems
- Sticks
- Billets
- Hog fuel
-

Experiments by Pari in 2007 [22] showed that piles of billets drought very efficiently in 8 months.
For chunks and stems, natural bulk drying is an interesting option because the air can easily penetrate the pile and dry matter losses will be low.
Natural wind drying experiments with different wood species showed that large piles of chunks generally dried well, heat generation within the pile was small or absent, microbial activity was negligible, and dry matter losses were low. The drying rate in a pile largely depended on the chunk dimensions. Despite these positive results, comminution to chip size is still the most commonly used method. One negative quality aspect of chunk wood is the inhomogeneous particle size distribution, which might create problems when burning the fuel [12].

6. *CHIP PILES CHARACTERISTICS*

Wood chip piles should be formed giving a conical shape, or linear, in order to induce a symmetric behaviour in any transversal section. As stated before, it is advisable to form the piles in a way that the distribution of moisture and particle sizes are the most homogeneous possible, avoiding accumulations of fines which may prevent air circulation and increase the risk of self-ignition.
In general, piles are advised to be formed under a roof, with good ventilation and preventing condensation of water under the roof. A concreted ground is advisable to facilitate loads.
In uncovered piles, outer layers of the piles are drier in summer. If possible, the use of a textile in winter months may be interesting for the trader, removing them in summer as far as there is no

[7] Hot Systems comprise processes which occur sequentially with a strong dependence of the following process on the performace of the previous, where the following must immediately take place after. An example of a hot system is the roadside chipping with exchangeable containers. In Cold Systems, this dependence is lesser, and an example is chipping at yard forming piles as chips fall.

forecast of intensive rainfall. Summer storms do not seem to affect significantly to the drying processes of uncovered piles.
Independently of the cover type, pile size is conditioned by the moisture of the chips, the green and bark content and the particle size. Material with moisture content over 30% (wb) and high green and bark content and an important proportion of fines should not form piles of more than 200 m3bv and 3-4 meters high. The drier the chips, the higher can be pile. Small piles (2-3 m high) are more sensitive to ambient conditions, especially to the season, than bigger piles (4-6 m).
A coarse comminution facilitates the drying processes, but attention must be paid in order to fulfil the requirements of the end-users. Otherwise, other solutions may be advised, such as screening, natural or artificial drying prior to chipping or artificial drying and medium and small wood chips.
Natural drying processes will never get moisture values under the equilibrium moisture content (EMC), corresponding to that in equilibrium with the surrounding air. In that case, biomass naturally dried in Europe can only reach values of 15-25% (wb), depending on the season and the location. In general, in a short time of about 6-8 months and with favourable conditions, moisture within wood chip piles can be reduced from 50% to 35% (wb), value which is enough for most of the furnaces.
When the moisture content of the batch of wood chips to be piled is less than 20% (wb), it is advisable to cover the pile with plastic. With such moisture, the microbial activity is low and the plastic helps to avoid rehydratation from rainfall. With higher moisture contents, results are not positive, as reported by CTFC from an experiment in 2007 with fresh chips with *Walki* paper and *TopTex* [20].
In that way, there are two ways to avoid losses and fungal growth in wood chip piles, which main aim is to have a low initial moisture content:

- comminution of dry material: in practice, raw material is left for one year or more, and moisture uses to reach 20% (wb). As stated in previous paragraphs, studies are under performance in order to optimize this storage time
- technical drying: there are different solutions, exposed later, which may reduce moisture down to 10-20% (wb). These solutions permit quick logistic responses but the energy efficiency of the system is heavily affected

Choosing one option of comminution and storage will depend mostly on the business perspectives of the entrepreneur and on the availability of space for different kind of storages.

FIGURE 142: Conical and elongated chip piles

E. TECHNICAL DRYING OF COMMINUTED MATERIAL

This concept applies when an active means is used for extracting moisture from wood chips. In that sense, *active* is understood as forced circulation of air in between the material with fans or similar means, with or without heat input for increasing the drying capacity of the air.
Drying the biofuel results in increased heat release per unit of fuel and a consequent reduction of the biofuel consumption for a given energy output. Drying the fuel also results in several additional benefits [26]:

- Increased furnace capacity
- Increased furnace efficiency
- Reduced quantity of stack gases
- Reduced particulate emissions

1. *WITHOUT ADDING HEAT*

By means of interrupted blowing of ambient air within the pile, the moist air is displaced out of the pile, allowing new air to absorb moisture and keeping active the convection within the pile, although there is a little decrease of the pile temperature and a loss of dry material through decomposition. In addition, as reported by Jirjis in 1995 [12], ventilating wood chip piles reduces the risk of self-ignition because the temperature of the pile is kept low. In winter, the drying capacity of this method is low, but still better than a continuous blowing of cold air. When the outdoor temperature rises, continuous blowing of air provides air with better conditions for absorbing water. The air can also be warmed up before blowing it into the pile. The forced ventilation with fresh air should be stopped when the relative humidity of the air is high, for instance when there is muggy weather [14].

FIGURE 143: Screen of the ventilation system of the Biomassehof Achental (Bavaria, Southern Germany)

In order to optimize the use of energy with fans, the piles should have even surfaces. In addition, an optimal height for wood chips can be estimated in 1 m for this kind of drying process [14]. The air circulation may be advised to be fixed between 180 and 540 m^3/h per square meter of ground occupied by the pile. Another approximation to the ventilation needed could be assessed in relation of the bulk volume, where at least 40 m^3/h for m^3 of solid wood should be provided. In order to accelerate the drying process, this value may be increased up to 150. In any case should the speed of the air be over 0,4 m/s, or the particles could be blown [14].

To calculate the power needed for this process, this formula may be used (adapted from [14]):

$$P_D = \frac{Q \cdot S \cdot R}{\eta_e \cdot \eta_f \cdot 3{,}6 \cdot 10^6}$$

Where:
P_D: power needed for drying (kW)
Q: specific flow (m^3/h of air per squared meter occupied)
S: surface occupied (m^2)
R: pressure drop (*resistance*) of the total height of the pile (Pa)
η_e: efficiency of the engine driving the fans
η_f: efficiency of the fans
Chunks can be dried relatively quickly by forced convective drying. For forced convective drying of chips, the high pressure drop over a product bed is a major disadvantage causing high energy costs. The pressure drop decreases considerably when the particle size increases. Compared to chips, forced convective drying of chunks requires much less energy [7].

2. *WITH ADDITION OF HEAT*

Using warm air for drying clearly shortens the time due to higher capacity of the warm air to absorb water. In this case, the air is heated 20-100 ºC over input temperature through a source of external heat. The value depends on the initial moisture content of the material, the quantity of material to dry and the available time to dry [14].
As said before, air with higher temperature can bear larger amounts of water that colder. When dimensioning drying devices, it has to be taken into account that the capacity of the air to absorb water is not fully efficient and never will get saturated at the drying conditions. In that way, one must account that the air will absorb 30 – 50% of the total absorbable water up to saturation [25].
In this case, the trader must take into account that the blowing system will now require a source of heat, which can be of diverse nature.
The energy need and power may be assessed with the following formula (adapted from [14]):

$$P_H = \frac{Q \cdot S \cdot \Delta T \cdot \rho_A \cdot c_A}{\eta_H \cdot 3600}$$

Where:
P_H: power of the burner (kW)
Q: specific flow (m^3/h of air per squared meter occupied)
S: area of the dryer
ΔT: increase of temperature (ºK)
ρ_A: specific density of the air at a given temperature and pressure (kg/m^3)
c_A: specific heat of the air (kJ·kg^{-1}·ºK^{-1})
η_H: efficiency of the heating system
In order to determine the increase of temperature at a given flow of air, it is necessary to know the initial and final moisture content of the biofuel (in order to determine the quantity of water to withdraw), as well as the initial temperature and relative humidity of the air. Air with 18ºC at 50% of relative humidity can bear, without neither adding nor loosing enthalpy, 2,5 g/kg of dry air. A small increase of the temperature of the air increases the humidity bearing capacity.
So, if a dryer needs to extract 2.800 kg/h of water from the biofuel having a flow of air of 30.000 m^3/h, this air needs a capacity to absorb 93.3 g of water per m3 (80.1 g/kg air, figure 0). At the previous given conditions (18ºC, 50% relative humidity) the air should be heated until 48 ºC and therefore under saturation conditions it could absorb all the water; because, as stated before, the air never absorbs all the absorbable water, it must be heated until around 60ºC.

A practical implementation of this method reports (personal communication *Biomassehof Achental*) a drying time of 18 days for piles up to 3 m.

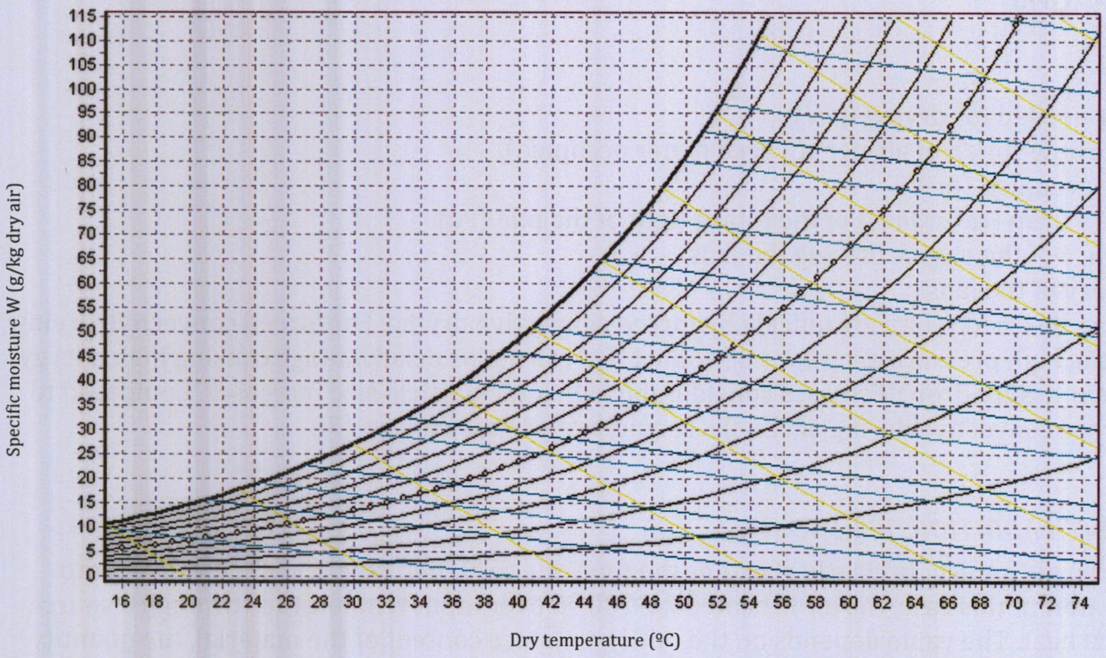


FIGURE 144: Psychrometric diagram. Source: software pSICRO (Polytechnic University of Valencia - UPV)

Thörnqvist reports from experiments in late 1970s and 1980 s[27], that the utilization of solar panels to pre-warm the air for drying chip piles of aspen saplings permitted a reduction of moisture content down to 7-8% (wet basis) after a period of 8 days. It is also reported that this process extended to 15 months led to a final moisture content of 11%.

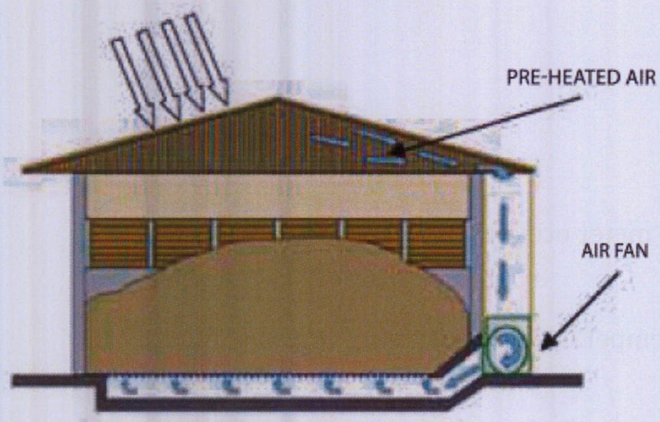


FIGURE 145: Pre-heated and forced ventilation system used at BL&TC Pölstal (Styria, Austria) Source [6]

a) Quick drying

When drying wood chips or hog fuel in specific devices designed to that aim, it usually has input from heat and, in addition, the biofuel is handled in a way that maximizes the time the surface of particles are in direct contact with flowing air.

b) Trommel-based dryers

With this process, wood chips are forced to circulate through a trommel which hot air is also forced to circulate in. At least two kinds of trommels are to be found in the market:

- Standard trommels, where the material enters from on side and it is forced to circulate only to the opposite side

Figure 146: Standard drying trommel for wood chips in installations of Ets Holzinger

- Tripe-circulation trommels (photograph 0), where the material circulates in both directions at different levels within the trommel. These kind of trommels are shorter than the standard ones, offering a clear advantage when available space is limited Hot gases after combustion (ca. 400 ºC) use to be the most appropriate heat input for these kinds of dryers.

Figure 147: Triple circulation trommel (Alfa). Courtesy of Contratos y Diseños Industriales S.A.

c) Belt dryers

With this process, chips are fed onto a belt forming a uniform layer, over which warm air is forced to circulate. Thus, wood chips are dry when they reach the end of the belt, and fall out of the system. This system is also indicated when the input heat flow has lower temperatures than those of exhaust gases of combustion (for instance, heat coming from cooling systems of engines, associated or not to electricity generation).
Some systems are equipped in a way that an upper layer of chips is recirculated within the system and a lower layer falls out. The recirculated layer is placed under newly fed chips. In that way, half layer of wood chips circulate twice within the dryer, saving some space in the facility.

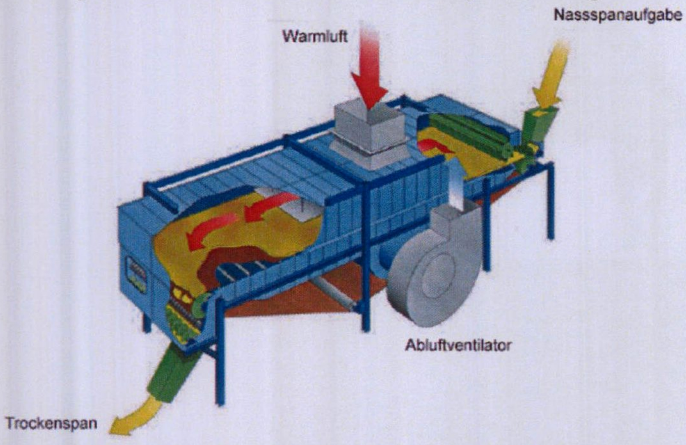


Figure 148: Scheme of the drying process of a belt dryer (KUVO belt dryer of Swisscombi)

At the end of the dryer fresh air can be blown in order to cool down the material for a safer handling.

d) Feed-and-turn dryers

According to the information provided in the webpage of the manufacturer *STELA Laxhuber GmbH*, hot air is blown through a double bottom – a grid bottom – through the product. A mobile paddle mechanism mixes and conveys the product during the whole drying time. This simple principle guarantees an almost maintenance- and trouble-free drying process. A carriage moves the paddle wheel across the drier for several times during the whole drying process. The direction is changed by final switches and the respective automatic control system. This combination guarantees an optimum mixing of the product and consequently a constant and homogeneous drying. This system avoids the risk of agglomeration even for heavily polluted or moist products. Wood chips can be dried in batches, for small quantities, or continuously, for large quantities.

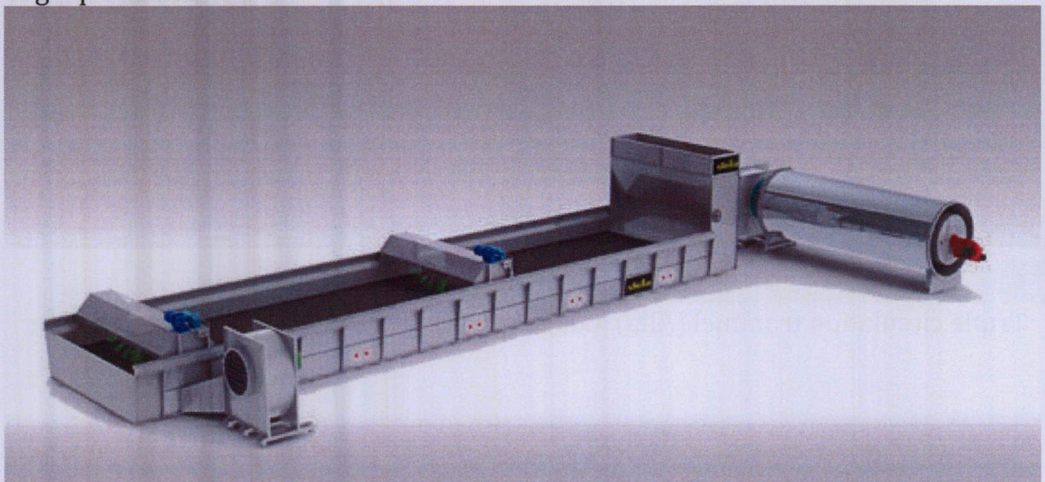


Figure 149: Feed and turn dryer (STELA Laxhuber GmbH webpage)

At the end of the dryer fresh air can be blown in order to cool down the material for a safer handling.

e) Slow drying

In these cases batches are located over a permeable floor from where the air flows, or also over special channels capable of blowing air into the pile. The installations may consist on silos located either indoor or outdoor, or also on containers specially designed for this purpose.
In case of buildings, part of them, or the whole, may be used for the drying installation, where part or the whole ground is prepared for blowing air into the material piled over it. When using containers, it may be considered to have more than one if drying different kind of materials. This is due to, because of the different resistance that different materials may offer for air flow, the fans may be fixed for that kind of material, facilitating an optimization of the energy use. It is important to note that the section of the ground hollow decreases with distance under the pile, in order to provide a uniform distribution of the warm air.

FIGURE 150: Storage building equipped with pre-heated ventilation. Piles are placed for drying with heights of 3 m

There is no problem to drive over the drying system when it is rigid constructed under the ground. This is not possible when pipes and flexible turrets are used for ventilating.
Box-dryers may be equipped with a dynamic floor in order to reduce the transferring processes. This can be even applied to exchangeable containers up to 40 m^3. In order to load these dryers front-end loaders are needed, and diverse solutions are also found for unloading. According to [6] this type of containers may cost up to 50.000 EUR.

Figure 151: Drying containers, associated to a biogas plant. Source: Lauber GmbH

Figure 152: Detail of the metallic ventilation grate. Source: Lauber GmbH

F. REFERENCES

[1] Álvarez, H., Fernández Golfín, J.I. 1992 *Fundamentos teóricos del secado de la madera.* Colección: Monografías INIA, núm 82. Instituto Nacional de Investigación, Tecnología Agraria y Alimentaria. Ministerio de Agricultura, Pesca y Alimentación.

[2] Anon. *Grundsätze zur Lagerung von Waldhackshnitzeln.* Bayerische Staatsforsten AöR. www.baysf.de

[3] Anon, 2007 *Richtiges Lagern von Holzhackschnitzeln für Heizwerke: Vermeidung von Bränden durch Selbstentzündung.* Merkblatt 01/07 of C.A.R.M.E.N. and Technologie- und Förderzentrum

[4] Codina, M., López, I. 2010 *Estudio de las características de la astilla forestal y buenas prácticas para su aplicación energética.* CTFC. Intrader Project infobio.ctfc.cat

[5] Ferrero, F., Lohrer, C., Schmidt, BM., Noll, M. and Malow, M. 2009. *A mathematical model to predict the heating-up of large-scale wood piles.* Journal of Loss Prevention in the Process Industries 22 (2009) 439-448

[6] Francescato, V., Antonini, E. and Zuccoli, L., 2010. *Wood fuels handbook.* Biomass Trade Centre I

[7] Gigler, J.K., van Loon, W.K.P., Sonneveld, C. 2004 *Experiment and modelling of parameters in influencing natural wind drying of willow chunk.* Biomass and Bioenergy 26 (2004) 507-514

[8] Gislerund, O. 1990 *Drying and storing of comminuted wood fuels.* Biomass 22 (1990) 299-244

[9] Hakkila, P. 2004. *Developing technology for large-scale production of forest chips.* Technology Programme Report 6/2004. Tekes - National Technology Agency

[10] Hogland, W., Bramryd, T., Persson, I. 1996 *Physical, biological and chemical effects of unsorted fractions of industrial solid waste in waste fuel storage.* Waste Management & Research (1996) 14, 197-210

[11] Jirjis, R., Gärdenäs, S. and Hedman, G., 1989. Storage in covered windrows - logging residues from softwood. Swedish University of Agricultural Sciences, Department of Forest Products, Uppsala, Uppsats no. 167

[12] Jirjis, R. 1995. *Storage and drying of wood fuel.* Biomass and Bioenergy, Vol 9, Nos 1-5, pp 181-190

[13] Jirjis, R. 2005. *Effects of particle size and pile height on storage and fuel quality of comminuted Salix viminalis.* Biomass and Bioenergy 28, 193-201

[14] Kaltschmitt, M., Hartmann, H. and Hofbauer, H. 2009 *Energie aus Biomasse. Grundlagen, Techniken und Verfahren.* Springer

[15] Kanzian, C., Holzleitner, F. 2010 *Automated data collection and reporting for transport, chipping and natural drying studies.* Lecture presented at the International Coference "Harvesting Forest Biomass: a Global State of the Art", Trento' 9th October 2010.

[16] Kent, T., Coates, E., Kofman, P. 2010 *Moisture content variation in forest biomass during storage.* Lecture presented at the International Conference "Harvesting Forest Biomass: a Global State of the Art", Trento' 9th October 2010.

[17] Kofman, P., Kent, T. 2009 *Long term storage and seasoning of conifer energy wood.* Coford Connects. Harvesting / transportation No. 20

[18] Lehtikangas, P. and Jirjis, R., 1995. Logging residues in covered windrows - influence of precipitation on fuel quality. Swedish University of Agricultural Sciences, Department of Forest Products, Uppsala, Research Notes no. 173

[19] López, E., Villén, D., Sebastián, F., Royo, F.J., Elías, A., Fernández, M. 2009 *Storage and natural drying techniques as a way to adapt woody feedstocks to cofiring requirements in mediterranean countries.* 17th European Biomass Conference and Exhibition, 29 June - 3 July 2009, Hamburg, Germany

[20] López, I. 2008 *Evolución de pilas de astilla bajo dos coberturas diferentes al aire libre: experiencia en Alp (Gerona)* CIDEU Bulletin 5, 85-95 (2008)

[21] Ortiz, L. 1989. *El secado natural de la fitomasa de residuos forestales.* PhD Thesis. ETSI Montes. Polytechnical University of Madrid.

[22] Pari, L., Ciriello, A. and Gallucci, F. 2008. *Consequence of SRF poplar wood harvesting method on energy content preservation.* 16th European Biomass Conference & Exhibition, 2-6 June 2008, Valencia, Spain

[23] Pari, L., Fedrizzi, M., Ciriello, A. 2008 *SRF poplar chips: stocking methods comparison to lessen fuel depletion from production to utilization.* 16th European Biomass Conference & Exhibition, 2-6 June 2008, Valencia, Spain

[24] Reisinger, K., Hartmann, H., Turowski, P., Nürnberg, K. 2009 *Schnellbestimmung des Wassergehaltes im Holzsheit.* Technologie- und Förederzentrum

[25] Repsol YPF. *Assecadors.* http://www.repsol.com/es_ca/productos_y_servicios/productos/glp_butano_y_propano/guia_de_los_glps/una_solucion_para_cada_sector/sector_agricola/secaderos/
[26] Springer, E.L. 1980 *Should whole-tree chips for fuel be dried before storage?* Research note FPL-0241. Forest Products Laboratory. Forest Service. United Stated Department of Agriculture
[27] Thörnqvist T. 1984. *Drying and Storage of Forest Residues for Energy Production.* Biomass 7, 125-134
[28] Vignote, S., Martínez, I. 2006. *Tecnología de la madera.* Mundi-Prensa Libros.
[29] Vignote, S., Picos, J., Zamora, R. 2010 *Características de las principales maderas utilizadas en Bizkaia: tecnología y aplicaciones.* Departamento de Agricultura de la Diputación Foral de Bizkaia

Partners in the project:

GOZDARSKI INŠTITUT SLOVENIJE
SLOVENIAN FORESTRY INSTITUTE

WALDVERBAND
• steiermark gmbh •

КАПЕ CRES | CENTRE FOR RENEWABLE ENERGY SOURCES AND SAVING

irbea | irish bioenergy association

ICPE BISTRITA

AIEL
ASSOCIAZIONE ITALIANA ENERGIE AGROFORESTALI

AVEBIOM

CENTRE FORESTAL / TECNOLÒGIC DE CATALUNYA

TUM
Technische Universität München

lk landwirtschaftskammer steiermark

BIOMASS TRADE CENTRE²

INTELLIGENT ENERGY
EUROPE